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PRENATAL AND POSTNATAL DEVELOPMENT AND FORM OF CRYPTS OF HUMAN PALATINE TONSIL

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Problems relating to the palatine tonsil have long been among the favorite topics of clinical writers, while the anatomy of this organ has also been subjected to many investigations and discussions. Nevertheless, there is no adequate, reliable body of information covering the development, gross morphology and relations of the tonsillar crypts and their associated glands and ducts. This is somewhat astonishing, as the anatomic peculiarities of the crypt system literally invite a pathologic condition of the tonsillar substance.

Many short descriptions of the crypt system in the postnatal palatine tonsil are on record, but these are general accounts of a superficial nature. Among the better descriptions is that of Levinstein,[1] who observed both that "the crypts run in three directions" and that "the group of acinous glands do not belong to the faucial tonsil, but to its neighborhood." Loeb[2] maintained that the majority of crypts open onto the superior surface of the tonsil and that the crypts in this location are larger and more profusely branched. Barnes[3] collected all the reliable information he could find on the tonsils. He mentioned that there are from ten to twenty crypts which extend in a general outward direction and that they are variable in length, size, complexity of branchings and caliber of lumen. He emphasized that the crypts emptying

Contribution 234 from the Department of Anatomy, Northwestern University Medical School.

1. Levinstein, O.: Ueber "Fossulae tonsillares," "Noduli lymphatici" und "Tonsillen," Arch. f. Laryng. u. Rhin. **22**:209, 1909.

2. Loeb, H. W.: Operative Surgery of the Nose, Throat, and Ear, for Laryngologists, Rhinologists, Otologists, and Surgeons, St. Louis, C. V. Mosby Company, 1914, vol. 1, p. 61.

3. Barnes, H. A.: The Tonsils, ed. 2, St. Louis, C. V. Mosby Company, 1923.

into the supratonsillar fossa drain poorly because they extend downward and outward and also that the crypts emptying behind the plica triangularis are poorly drained. Closely related to the pathologic condition of the tonsil is the manner of the drainage of the mucous glands. There is much misinformation on this subject, many writers claiming that the ducts of mucous glands open into the crypts, but Maximow and Bloom [4] stated correctly that this is of rare occurrence. Also Kahler [5] has recently stated that the crypts of the palatine tonsil are poorly drained because the ducts of mucous glands do not empty into them.

It is clear that a proper understanding of the adult crypt system is best approached through a study of its development. Stöhr [6] briefly considered the general development of the crypts but did not furnish any details. On the other hand, Hammar [7] has published an important contribution which deals with certain aspects of the detailed study of prenatal tonsillar development. He constructed models of the prenatal crypt system and reported that portions of it undergo degeneration. Among Hammar's models of human palatine tonsils occur stages comparable to some of those in our own series. Although Hammar did not describe the crypt system in detail, his illustrations serve as valuable aids for comparison. A discussion of relevant parts of Hammar's study in relation to our own is included in a later section of the present report.

It is our purpose to describe and discuss the life history of the crypt system in the human palatine tonsils as determined from a study of serial sections and wax reconstructions of significant stages from the first buddings of prenatal life to the atrophic tonsil of old age. We are firmly of the opinion that methods of reconstruction (combined with an examination of the histologic condition of the tissues involved) constitute the only reliable means of obtaining accurate, detailed information on these matters.

MATERIAL AND METHODS

The majority of the postnatal material was obtained at clinics, where the specimens (from patients of known history) were promptly fixed in a 10 per cent dilution of solution of formaldehyde U. S. P. Subsequently all such material was carefully inspected, and the majority of the specimens were discarded as unfit because of a patent pathologic condition or damage in removal. In the end ten apparently normal tonsils were selected; these were sectioned serially and stained with hematoxylin and eosin. The ages in years of the subjects from whom the specimens were taken were as follows: 3, 5½, 6, 8, 10, 13, 17, 21, 25 and 65.

4. Maximow, A. A., and Bloom, W.: Textbook of Histology, Philadelphia, W. B. Saunders Company, 1934, p. 364.

5. Kahler, O.: The Tonsil Problem, J. Laryng. & Otol. **48**:2, 1933.

6. Stöhr, P.: Die Entwicklung des adenoiden Gewebes der Zungenbälge und der Mandeln des Menschen, Anat. Anz. **6**:545, 1891.

7. Hammar, J. A.: Studien über die Entwicklung des Vorderdarms und einiger angrenzenden Organe, Arch. f. mikr. Anat. (Abt. 2) **61**:404, 1903.

A microscopic study of this series showed the tonsils from the 3, 21 and 65 year old subjects to be most favorable for reconstruction. By good fortune such stages also represent well the periods of childhood, maturity and old age. The reconstructions were made by the wax plate method of Born at a magnification of 25 diameters.

Thirty-one additional specimens from subjects ranging in age from the beginning of the third lunar month to 1 month postnatal were collected from aborted, stillborn fetuses and from one infant who died soon after birth. In most instances both tonsils of each specimen were sectioned serially and stained with hematoxylin and eosin. This series also received careful microscopic study, and seven wax reconstructions magnified from 75 to 100 diameters were made of five significant stages in the development of the crypts. The age in lunar months and the crown-rump lengths of the specimens modeled were as follows: 100 mm., 3.5 months; 130 mm., 4.2 months; 210 mm., 6 months; 230 mm., 6.5 months; 340 mm., 10 months (two specimens), and ? mm., 1 month postnatal. In the fetal and 1 month postnatal stages, tracings made with an Edinger projection apparatus followed the basal layer of epithelial cells to include the solid ingrowths as well as those variously hollowed, whereas tracings of the 3, 21 and 65 year stages followed the free epithelial surface of the completed crypts.

The crypts on all the resulting models were then counted, and their form, relationships and peculiarities were observed and recorded. In counting and classifying the crypts a first order crypt was considered to be any primary invagination from the tonsillar fossa. Similarly, a second order crypt was considered as any branch of a first order crypt and so on. Such crypts as were apparently isolated were classified as cysts. Cystlike crypts appended by a narrow epithelial neck to the rest of the system were termed vesicles. In addition, the position and relationships of the peritonsillar mucous glands and the mouths of the ducts draining these glands were observed and recorded.

Finally, the surface area represented by the crypts in the tonsil of the 21 year old subject was computed by measuring the length and circumference of the crypts as modeled. Irregular crypts were divided into segments before measuring. The superficial surface area of the pharynx (exclusive of the crypts) in one adult cadaver was also calculated approximately by removing the complete pharyngeal mucous membrane, spreading it flat and dividing it into convenient areas for measurement.

The collection of material from subjects ranging in age from 3 years to 65 years, the preparation of sectioned series and the construction of the provisional set of original models (3, 21 and 65 years) was done by one of us (J. T. M.). Later the slides were extensively restudied, the original tracings rechecked and the models corrected when errors were found to exist by another of us (W. L. M.). The problem was assigned and generally supervised by the remaining author (L. B. A.), who also independently rechecked the entire series of tracings before the final alterations of the model were made as well as the alterations themselves. The collection of the fetal material and the 1 month postnatal specimen, the preparation of serial sections of these stages and the construction of seven new models were pursued independently by W. L. M. The interpretation of the models and preparation of the manuscript have resulted from the collaborated efforts of W. L. M. and L. B. A.

OBSERVATIONS

Tonsillar Fossae and Plicae.—The plica supratonsillaris is prominent in the late prenatal and the 1 month postnatal specimens modeled; it is far better developed in these later stages than in the 3.5 and 4.2 month

prenatal models. The plica triangularis is also constant throughout this period. Separation into anterior and posterior fossae is indicated in the earlier stages (3.5 and 4.2 months), although no distinct plica intratonsillaris (of Hammar) could be found. Hammar [7] demonstrated the bilobed nature of the tonsil by modeling the lymphoid tissue. This lobation is not so readily recognizable when the epithelium alone is modeled. The anterior fossa exceeds the posterior fossa in size and in the complexity and number of its ingrowths. Since there were no retrotonsillar plicae, it follows that in all instances the tonsillar fossae were not marked off sharply from the pharyngeal wall. Descriptions of the supratonsillar fossae at various stages will be given in conjunction with the description of their respective crypt systems.

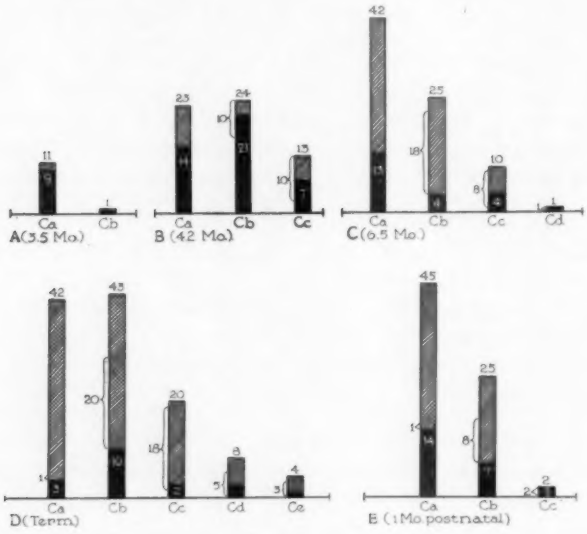

Fig. 1.—Graphs showing the numbers of crypts in models of fetal tonsils at 3.5, 4.2 and 6.5 months and in models of the tonsils at full term and 1 month after birth. Note the gradual increase with age in the number and order of crypts in the fetal tonsils; also the increase in the number of vesicles. In the graph for the model of the tonsil at full term note the increase in the number and order of crypts and in the number of vesicles over the 6.5 month stage (*C*). Observe also the marked decrease in the number and order of crypts (except first order) and in the number of vesicles in the tonsil of the 1 month old infant as compared with those for the infant at full term. This difference is accounted for by the disappearance of many vesicles. *Ca* indicates the first order crypts; *Cb*, the second order crypts, etc. Solid primordia of crypts are indicated by solid shading, hollowed crypts by hatched shading. The numbers opposite the brackets refer to the number of crypts which are vesicles. The total number of crypts (both solid and hollow) is indicated at the top of each column.

Tonsillar Crypts.—The development of the crypt system dates from the third lunar month. Arising from the lateral epithelial wall of the tonsillar fossa in the model made from the 3.5 month fetus are three long, cylindric ingrowths which curve downward and outward, and eight lesser, simple budlike ingrowths, the largest of which is associated with the supratonsillar recess (fig. 4 *A*). The first of the cylindric ingrowths just mentioned arises from the supratonsillar fossa, the second from the midregion of the tonsillar fossa and the last (which bears a single solid second order branch) from the lower part of the same fossa.

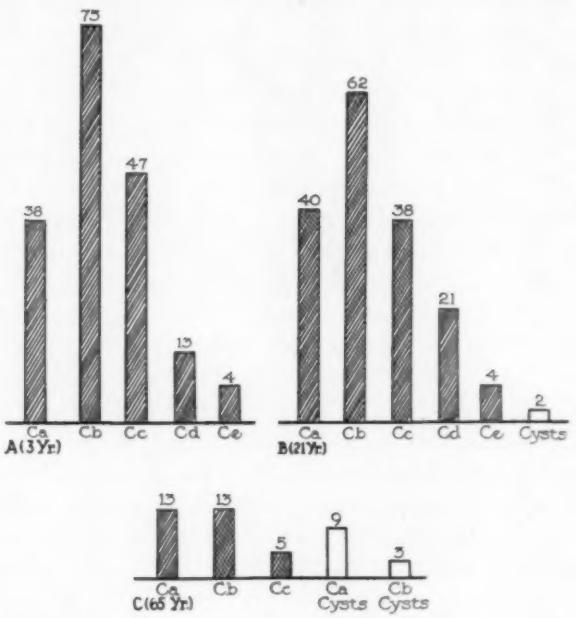

Fig 2.—*A*, graph showing the numbers of crypts in the model of a tonsil at 3 years. Solid crypt primordia and vesicles are no longer present. The number of first order crypts remains relatively constant as compared with that for the specimens at term and 1 month after birth (fig. 1 *D* and *E*). By contrast, the number of second and third order branches has increased strikingly, while new fourth and fifth order crypts have appeared.

B, graph showing the number of crypts in the model of a tonsil at 21 years. The number and order of crypts is essentially as in the model of the tonsil at 3 years. The growth of the crypts, especially those located inferiorly, characterizes the interval since childhood, but this feature is not indicated in the graph.

C, graph showing the number of crypts in the model of a tonsil at 65 years. Not only is there a great decrease in the total number of crypts of all orders but also those of the fourth and fifth orders have disappeared as such. Correlated with the degenerative process, cysts are numerous.

Ca indicates the first order crypts; *Cb*, the second order crypts, etc.; *Ca Cysts* indicates primary cysts and *Cb Cysts*, branches of primary cysts.

The mouths of two of the larger, more extensive ingrowths have already appeared through the desquamation of the central cells most remote from the basal layer. These central cells are larger and paler than the basal cells from which they arose; the farther they are pushed away from the basal cells and the older they become, the nearer do these cells approach the end of their natural life cycle, which terminates in desquamation. This "hollowing out" process in the region of the mouth of a crypt has taken place without the desquamated cells having compacted into an epithelial plug, as will be described for deeper portions of the system. It is probable that some of the crypts so created are later absorbed, wholly or in part, into the growing expanding wall of the tonsillar fossa. At this stage the crypt system as a whole is relatively insignificant (fig. 1 *A*). The epithelium is characterized at its actively proliferating basal border by several layers of apparently similar cells which are not sharply demarcated by a basement membrane from the surrounding mesenchyme. All the rapidly growing portion of an invading crypt process shows epithelium of this character.

In the model of the tonsil of the 4.2 month fetus the epithelium of the fossal wall associated with the epithelial ingrowths is greatly thickened owing to the burst of proliferative activity which characterizes this period of tonsillar development. This thickening of the epithelium is not general but is confined to irregular, local areas which represent the expanded bases of solid epithelial ingrowths (fig. 3 *A*). The lateral wall is dotted with numerous pits and still deeper recesses of varying caliber and depth; these indicate the mouths of the first order crypts already in various stages of lumen formation. This model shows many simple budlike crypts and seventeen cylindric (circular or oval in section) first order epithelial ingrowths, which are of varying length and diameter (fig. 4 *B*). These seventeen ingrowths take an approximately parallel course in an inferior direction. Eleven of them bear second order branches, totaling twenty-four in all. Nineteen of the second order branches project in an inferior direction. Study of later stages indicates that these downward growing crypts and their branches (second and third order), which represent the major part of the crypt system at this period, are destined to atrophy and disappear. Even at this period the beginning of this process is indicated by the fact that twenty crypts are attached by relatively constricted necks, while still others show early stages of constriction. Reference should be made to figure 1 *A* and *B* to appreciate the advance of the crypt system during the period (scarcely three weeks) since the first stage described.

The tonsil of the fetus at 6.5 months shows a tonsillar fossa differing in no essential detail from that of the preceding stages. By contrast, the crypt system shows almost double the number of first order crypts (forty-two), most of which have hollowed out (fig. 1 *C*). The

number of second and third order crypts remains practically unchanged (twenty-five and ten), but at this stage most of the second order crypts possess lumens. One fourth order branch, a small prevesicle, is present in the model. It is to be noted that most of the second, third and fourth order crypts have narrow, constricted necks (fig. 5). In the present report such crypts will be designated as vesicles (fig. 3*B*, V_2) or, if solid, as prevesicles (V_1); the larger vesicles of this specimen averaged

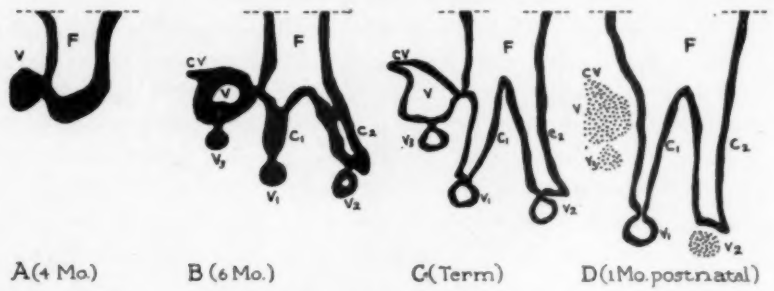

Fig. 3.—Diagrams summarizing some of the more important features of the developing crypt system.

A represents the thickened epithelium of the tonsillar fossa (*F*) during the fourth month. A solid first order crypt (prevesicle) (*V*) arises from its wall.

B illustrates the advances that characterize the sixth month. The epithelial vesicle (*V*) has grown larger, and its central cells have started to degenerate and thus form an epithelial plug. It still retains a narrow solid neck. From the wall of the vesicle are growing out a flat platelike bud (*CV*) and a prevesicle (V_3). Two new crypts (C_1 and C_2) of the definitive flat platelike type have also appeared. C_1 is almost completely solid, although the formation of a lumen is beginning proximally; this crypt presents at its end a prevesicle (V_1). The crypt C_2, which shows both proximal and distal formation of a lumen, presents a small vesicle (V_2) with a narrow solid neck.

C shows many features of the crypt system at term. The large vesicle (*V*) has completely hollowed out, its lumen containing an epithelial plug and scattered lymphocytes; nests of lymphocytes appear within parts of the thinning epithelium. This main vesicle has a small diverticulum (*CV*) and also a vesicle (V_3) appended by a narrow solid neck. The flat platelike crypts C_1 and C_2 have completed their lumens, C_1 by means of a progressive degeneration of cells proximodistad and C_2 by simultaneous proximal and distal hollowing. The appended vesicles (V_1 and V_2) have likewise completed the formation of lumens, but their necks are still solid. At this period, C_1 and C_2 are first order crypts. Vesicle *V*, originally in relation to the sinus, now appears to arise from the base of C_1 and conforms to our definition of a second order crypt. *CV* and V_3, appended to *V*, are therefore third order crypts.

D illustrates an early postnatal specimen. The large vesicle (*V*), with its diverticulum (*CV*), is completely cut off and highly degenerate. V_2 and V_3 have also degenerated and lost their attachments. The central cells in the neck V_1 have broken down to afford open communication with its mother crypt (C_1). From the resulting residue of crypts, the permanent system will regenerate, without, however, any further increase in the number of first order crypts.

from 0.25 to 0.4 mm. in the greatest diameter. The essential difference between the crypt system at 4.2 and that at 6.5 months lies in the fact that in the latter there are many new ingrowths without constricted attachments (fig. 3*B*, C_1, C_2). These are of paramount significance, since they represent the primary permanent crypts; among them already occur those of the large platelike type, either straight or curved, such as is characteristic of the models of the adult tonsil. The model of the tonsil of the fetus at the 6 month stage shows no important differences from that of the 6.5 month stage just described.

Examination of the model of the tonsil at term reveals a more advanced crypt system than that found in the 6 month and the 6.5 month fetal specimen (fig. 6). The straight or curved platelike type of crypt predominates both in number and in size. A few crypts of the second and third order, now more advanced, also have assumed this shape. The number of first order crypts is unchanged (forty-two) (fig. 1*D*). On the other hand, the number of second order crypts has increased nearly twofold to a total of forty-three—many in the form of epithelial vesicles, as in the 6.5 month specimen (fig. 3*C*; the larger vesicles of this specimen averaged from 0.6 to 0.8 mm. in greatest diameter). Similarly, the number of third order crypts has doubled (twenty); almost all these are epithelial vesicles. Of the twelve fourth and fifth order crypts, eight are vesicles or prevesicles. A study of the second model of the tonsil at term exhibits no important differences or additional features.

In the model prepared from an infant 1 month old an astonishing reduction in the total number of crypts is apparent (figs. 1*E* and 7). Yet the number of first order crypts remains unchanged (forty-five), while the straight or curved platelike type of crypt still predominates both in number and in size. On the other hand, the second order crypts are reduced almost one-half (twenty-five) as compared with the same structures one month earlier. Moreover, the number of third order crypts is negligible (two), and no fourth or fifth order crypts are represented. These differences from the new-born stage are accounted for by the fact that the numerous vesicles (and crypts attached to them) of the earlier period have finally cut off from the permanent crypt system and have completed their course of atrophy and degeneration (fig. 3*D*). This progressive degeneration of part of the crypt system can be further demonstrated through a microscopic study of the tonsil at graded stages in its development.

Study of the model representing the tonsil of a 3 year old child impresses one with the increasing complexity of the crypt system (fig. 8). All the crypts shown in this model have completed the formation of a lumen. Most of the larger crypts are of the straight, curved or

irregularly platelike type. However, some are budlike and others irregularly cylindric; also represented are a few long, narrow, sinuous crypts, but the platelike type is predominant in size and number. A greater variety of shapes is found accompanying the increase in the number and complexity of the crypts. The majority of first order crypts and many second order crypts have narrow necks. The crypts in the superior half of the tonsil are larger, longer and more profusely branched. By contrast, the crypts in the lower half are smaller and shorter. That a higher development of the superior half is characteristic of this period is supported by Hammar's [7] model of the tonsil of an 8 year old girl and

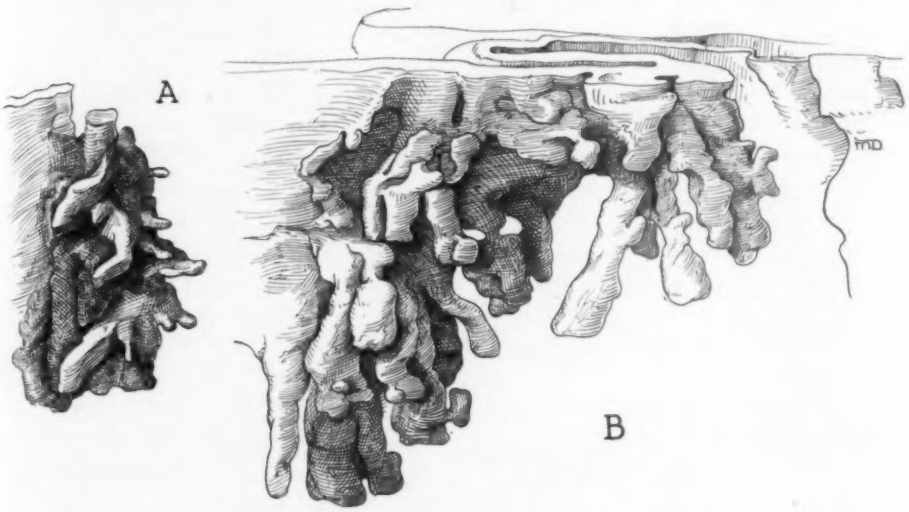

Fig. 4.—*A*, anterolateral aspect of the crypt system in the left tonsil of the 3.5 month (100 mm. crown rump) fetus (× 25). Three long curving cylindric crypts and eight small, budlike ingrowths constitute the crypt system. The bulging, dark masses in the background represent the tonsillar fossa; at the top center is the cut off supratonsillar fossa from which a prominent small crypt is budding. Mucous glands were not modeled.

B, lateral aspect of the crypt system in the right tonsil of the 4.2 month (130 mm. crown-rump) fetus (× 25). The drawing shows at the top a section through the superior part of the tonsillar fossa to demonstrate the relation of the crypts to the lateral fossal wall. The increase in the complexity of the crypt system should be compared with the stage three weeks earlier (4 *A*). Note the numerous cylindric crypts and also many with variously constricted necks (vesicles). The supratonsillar fossa and mucous glands were not modeled.

the gross appearance of children's tonsils when removed. The general direction in which the crypts point is laterad, but several second to fifth order crypts point superiorly. Cystic crypts are not represented, although one crypt resembles a prenatal vesicle with a narrow, open neck.

Whether or not this vesicle actually is a survivor of the prenatal crypt system could not be determined. One anastomosis was found between a first and a second order crypt. The number of first order crypts remains relatively constant (thirty-eight) as compared with the specimens from infants at term and one month after birth (fig. 2*A*). However, the number of second and third order branches has increased strikingly (seventy-five; forty-seven). Fourth and fifth order crypts are also well represented (thirteen; fourteen). The supratonsillar fossa is not well defined and cannot be distinguished from a crypt.

The model of the tonsil at 21 years resembles that of the 3 year specimen in many details, including the order and number of its crypts, but the crypts are spaced farther apart, owing perhaps to the greater abundance of lymphoid tissue (fig. 9). In the inferior half the crypts are longer and larger but not fundamentally more complex than those in the inferior half of the 3 year old tonsil; as a result, this region is filled in equally with the superior half. The completion of growth inferiorly is the most outstanding advance since early childhood. That this inferior filling in is characteristic of maturity is supported by a well rounded out model of the lymphoid mass of a tonsil at 40 years made by Hammar.[7] Since the lymphoid tissue follows the crypts and varies with them, one can infer that the crypts of this specimen had grown to match those of the superior pole, as had ours. Similarly, it is the experience of clinicians that essentially normal, mature tonsils are not crypts. The number and order of crypts are essentially as in the model deficient in tissue at their inferior poles. The shape of the crypts in this mature specimen is in general quite like those of the preceding stage; however, they can be more advantageously studied because of their wider spacing. Two small cystic crypts occur near the capsule; also a typical, attached vesicle containing an epithelial plug is demonstrable. There are two anastomoses, each of which connects a pair of first order at three years (fig. 2*B*). The antler-like arrangement of the crypts in the superior half of the tonsil can be seen well in figure 10. Three large and three small first order crypts open into the supratonsillar fossa.

The model of the tonsil at 65 years presents a striking example of an atrophic crypt system (fig. 11). There is a great decrease in the total number of crypts. Most of those still retained are confined to the superior half of the tonsil, while the inferior half is almost barren. This finding is supported by the external shape of the senile tonsil as obtained at operation; its inferior pole is thin and deficient in substance. The decrease in the length, size and complexity of the crypt system has been accompanied by a simultaneous reduction in lymphoid tissue and a compensatory invasion of fibrous connective tissue from the capsular region. Correlated with the degenerative processes, cysts are numerous. They are of two kinds: globular, and straight or curved platelike cysts;

Fig. 5.—Posterolateral aspect of the crypt system in the right tonsil of the 6.5 month (230 mm. crown-rump) fetus (× 25). Among the numerous vesicles with narrow necks, note the presence of new ingrowths which are large and platelike (straight or curved) and lack constricted attachments; these represent the future, permanent crypts. A prominent supratonsillar fossa rises in the upper third of the drawing; its lateral wall bears several crypts. Black masses, located mostly along the anterior and superior aspects of the tonsillar fossa, represent peritonsillar mucous glands. A striped mass, located inferiorly, indicates a mass of cartilage.

the latter are derived from crypts of this same type. No anastomosing crypts were found. Only first, second and third order crypts (thirteen, thirteen and five, respectively) are represented (fig. 2 *C*). The supratonsillar fossa is small and shallow; two large crypts and one small crypt open into it.

Area of Crypt Epithelium.—The determination of the approximate surface area represented by the epithelium of the crypt system of the 21 year specimen of palatine tonsil gave the following results. The total surface area of the crypts of one tonsil was 295 square centimeters (45.7 square inches). Hence both tonsils would contain some 91 square inches (590 square centimeters), or 0.64 square feet, of crypt epithelium.

For comparison, the total superficial area of one pharynx (exclusive of its crypts) was measured and found to contain only 44.8 square centimeters (6.9 square inches). This is but one thirteenth of the total area of both palatine crypt systems.

Lymphoid Tissue.—Lymphocytes are already present early in the third month as condensations at the tips and sides of the epithelial ingrowths and around the regional blood vessels. Typical diffuse lymphoid tissue is found in the fourth lunar month. Numerous lymphocytes are seen in the large lymphatic channels and in the smaller lymphatic radicles within the lymphoid tissue. Primary nodules (i. e., without germinal centers) are present from the sixth month on. No secondary nodules (i. e., with germinal centers) occurred in the prenatal or the 1 month postnatal specimen. Large secondary nodules with large pale centers are numerous in the abundant lymphoid tissue of the tonsil at 3 years as well as in all the later series studied prior to the period of involution. Secondary nodules are also present in the 65 year stage, but they are smaller. Lymphocytes invade the epithelium of the early solid ingrowths and are commonly seen in the walls and lumens of all epithelial vesicles as well. The migration of lymphocytes through crypts other than vesicles is less noticeable in the fetal stages, whereas lymphocytes are abundant in parts of the epithelial walls of all crypts in all the postnatal specimens studied.

Mucous Glands and Ducts.—The ducts draining the peritonsillar mucous glands arise from the epithelium in and around the tonsillar fossa in the latter part of the third month. Since this early, independent origin is before the crypt system has attained any prominence, it explains why ducts are rarely found draining into crypts. The following paragraphs contain summarizations of the data concerning glands and ducts in the various models.

The model of the tonsil of the fetus at 3.5 months (compare fig. 4 *A*) shows thirteen ducts; eleven open on the epithelial surface anterior

Fig. 6.—Posterolateral aspect of the crypt system in the right tonsil of a full term (340 mm. crown-rump) fetus (× 25). The straight or curved platelike crypts predominate both in number and size, and a few second and third order crypts have also assumed this shape. Vesicles are more numerous than at the previous stage (fig. 5). The supratonsillar fossa subdivides into two parts, which are shown just in front of the most superior gland mass. Most of the peritonsillar mucous glands (in black) lie along the anterior border of the tonsil and near the superior and inferior poles, although another gland mass is situated posterior to the superior pole.

to the tonsillar fossa, and two empty into the supratonsillar fossa. Gland masses are not sufficiently developed at this stage to be modeled with ease.

The model of the tonsil at 4.2 months (compare fig. 4 *B*) shows ten ducts; nine open along the anterior margin of the tonsillar fossa, and one opens into the supratonsillar fossa. No gland masses were modeled.

The model of the tonsil at 6.5 months (fig. 5) shows seven gland masses located along the anterior border of the tonsil between the superior and the inferior pole. These glands are drained by thirteen ducts; eleven of them open along the anterior margin of the tonsillar fossa, while the remaining two open on the epithelial margin of the inferior pole.

The model of the tonsil of an infant at full term (fig. 6) shows eight gland masses arranged along the anterior margin and overlapping the two poles. Twelve ducts pass from these gland masses to open on the epithelial margin surrounding the tonsillar fossa.

The model of the tonsil of a 3 year old child (fig. 8) shows five peritonsillar gland masses located anterior to the tonsil and extending from the superior to the inferior pole. These connect with eight ducts which open on the epithelial surface along the anterior margin of the tonsil.

The model of the tonsil at 21 years shows three gland masses; two smaller masses lie at the superior pole between the crypts and the free surface of the tonsil (fig. 10), and one long spiral mass (consolidated from earlier discrete masses) extends from the superior pole to the inferior pole along the anterior border of the tonsil (fig. 9). One duct from one of the superior gland masses and another from the superior part of the long, spiral gland mass open into the supratonsillar fossa. The remaining five ducts open on the epithelial surface along the anterior margin of the tonsil. In four instances the dilated ends of ducts were surrounded by lymphoid tissue and resembled simple crypts. These, however, cannot be considered as true crypts of the palatine tonsil.

The model of the tonsil at 65 years (fig. 11) shows five gland masses. Two of these are located at the superior pole and two at the inferior pole, while the remaining small mass lies anterior to the tonsil. Six ducts, draining the larger of the superior masses, open superior to the supratonsillar fossa. Two ducts leave the middle gland mass; one opens on the epithelium of the anterior surface of the tonsil and the other in the mouth of a small crypt. The gland masses at the inferior pole drain by means of two ducts opening on the epithelial surface of the inferior pole of the tonsil.

Cartilage.—In the prenatal and 1 month postnatal specimen both prehyaline and hyaline cartilage were commonly found near the mucous glands, located between them and the lymphoid tissue (fig. 5). Hyaline cartilage in this position was also found in the tonsil of the 3 year old

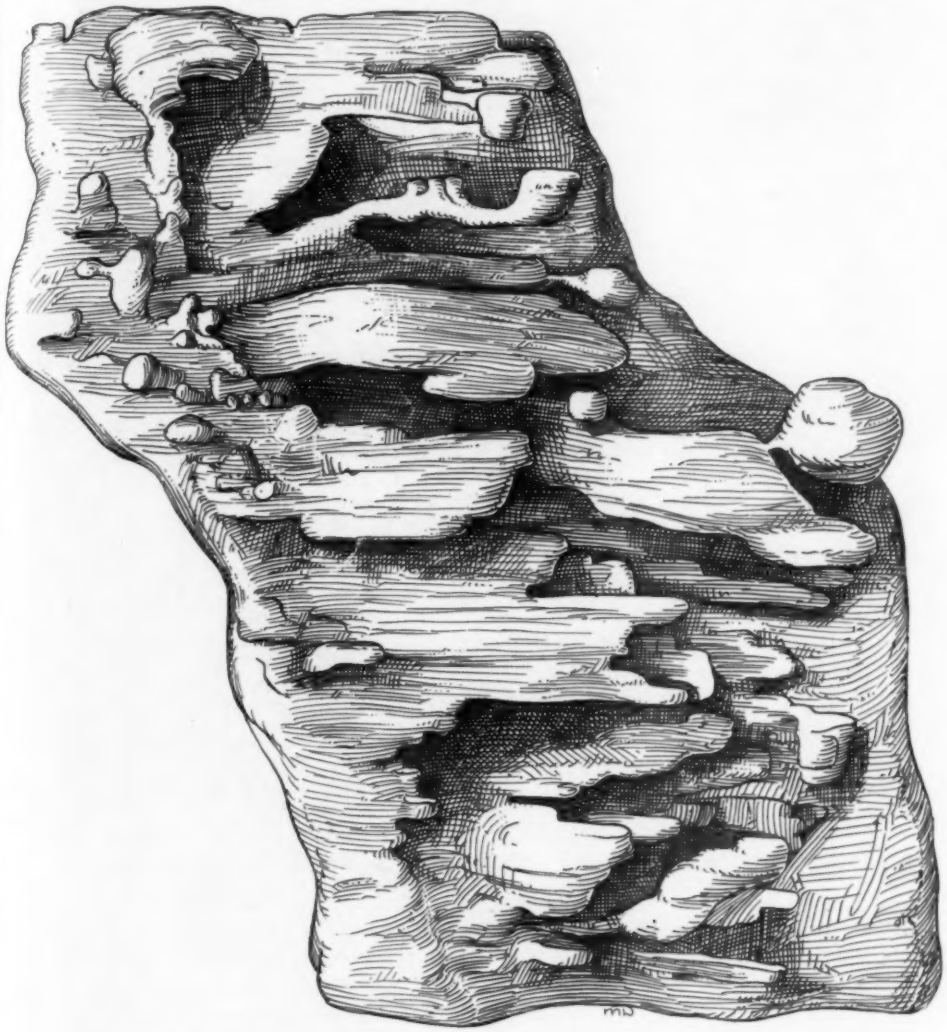

Fig. 7.—Lateral aspect of the crypt system in the right tonsil of an infant 1 month old (× 25). Observe the simplicity in comparison to the previous stage one month younger (fig. 6). The astonishing reduction in the total number of crypts is brought about chiefly by the degeneration of numerous vesicles, but the number of first order crypts is not affected. The straight or curved plate-like crypts still predominate. The supratonsillar fossa is relatively inconspicuous in this specimen. Mucous glands were not modeled.

child at the inferior pole. According to Weller,[8] cartilage between the lymphoid tissue and the mucous glands is a common occurrence (21 per cent) in the adult tonsil. The finding of cartilage in this location in prenatal stages lends proof to Weller's contention that the occurrence of cartilage situated here in the adult is a common normal condition and has no pathologic significance. It is reasonable to assume that this cartilage is derived from the mesenchyme of the branchial arch, since such an assumption is in harmony with the known prospective potency of this tissue.

THE LIFE HISTORY OF THE CRYPT SYSTEM

Before one can interpret satisfactorily the crypt system of childhood and adult life on the basis of what is known of the prenatal system, the interrelationships between the growth of lymphoid tissue and epithelium must be understood as well as certain interpretations, especially that of the incorporation of parts of the fetal tonsillar fossa to form one or more mouths of crypts.

A palatine tonsil may be defined as a massive development of lymphoid tissue lying within the tunica propria of the pharyngeal mucous membrane and immediately beneath the surface epithelium and the hollowed-out epithelial ingrowths, with which it is closely and peculiarly related. Thus, two components are involved, lymphoid tissue and epithelium, and it is with these two tissues that the developmental interrelationship deals. The epithelial entodermal component should logically be considered first, because it is the dominant and aggressive factor in the early stages of development and thus determines largely the form and relations of the fetal tonsil. The mesodermal lymphoid tissue can properly be considered as the modifying component, because it later modifies the form and relations primarily determined by the epithelium. This concept is fundamental and inclusive and serves as a valuable interpretive aid.

During the third month of fetal life a portion of the palatine epithelium at the site of the future tonsil proliferates and invades the mesoderm to form a small pocket, or palatine recess, which is the forerunner of the fetal tonsillar fossa. The results of this invaginative process, as commonly seen in the fourth fetal month, are much as though one had applied a small flat spatula to the surface of the palatine epithelium, at the same time pushing inward and forward to form a pocket that extends anteriorly toward the palatoglossal arch (fig. 4*B*). In the same manner, one could produce additional similar pockets, variable in size, shape and direction, and thus duplicate the numerous variations

8. Weller, C. V.: The Incidence and Histopathology of Bone and Cartilage in the Tonsil, Ann. Otol., Rhin. & Laryng. **32**:687, 1923.

of the fetal fossa cited by Mosher.[9] The pharyngeal, or faucial, walls of these single or multiple pockets, or fossae, are simple folds of mucous membrane (called plicae), which have been specifically named by various authors according to their shape or position; some of these are quite constant while others are variable, as is also true of the fossae. Smaller secondary ingrowths, arising in the main from the primary invagination, become the solid primordia of the future tonsillar crypts.

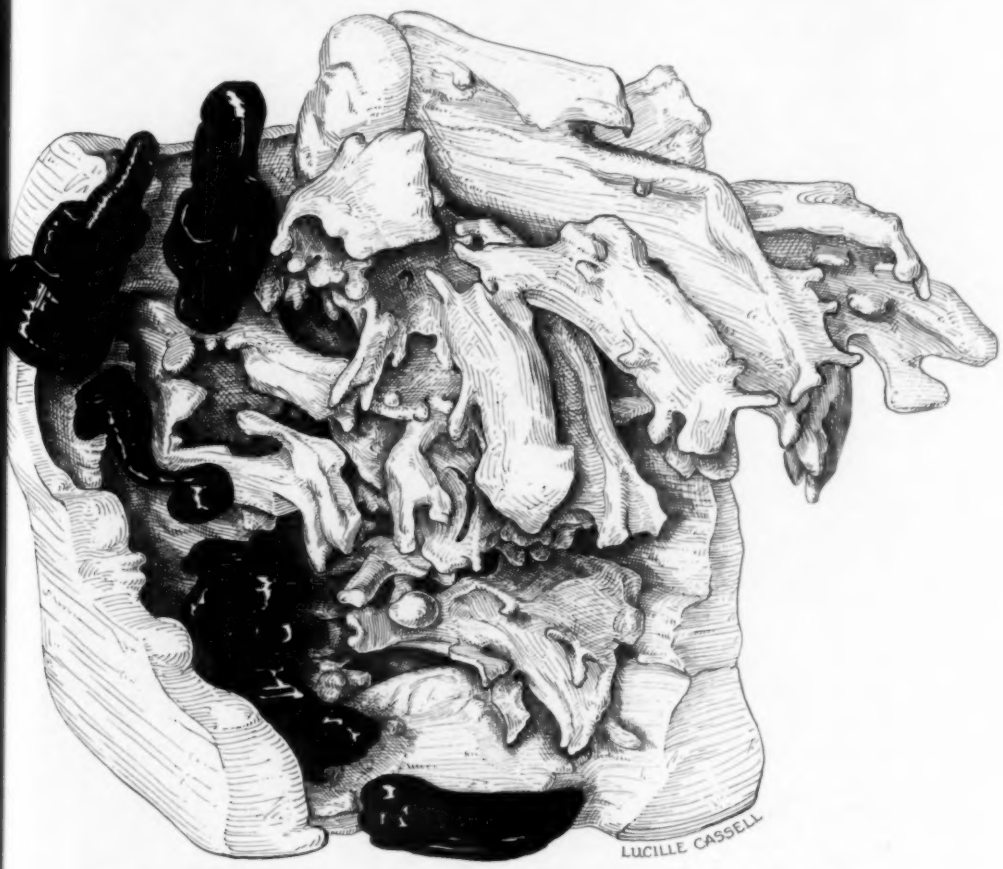

Fig. 8.—Anterolateral aspect of the crypt system in the left tonsil at 3 years (× 25). Increased complexity has followed the earlier postnatal destruction of crypts. Most of the larger crypts are of the platelike type. Most first order crypts and some of the second order have narrow necks. The crypts in the superior half of the tonsil are larger, longer and more profusely branched. No cystic crypts remain. Mucous glands (in black) lie along the anterior border of the tonsil from pole to pole.

9. Mosher, H. P.: The Tonsil at Birth, Laryngscope **13**:817, 1903.

During the period of this epithelial invasion, the lymphoid tissue gradually differentiates; it underlies the epithelium and is closely applied to it. At the time of birth this concentration of lymphoid tissue has attained no considerable bulk, even though the larger localized masses cause small irregular bulgings of the overlying epithelium. Within the first year after birth the lymphoid tissue undergoes marked proliferation, and it is at this time that its modifying influence first becomes apparent. There may be from one to several local masses of proliferated lymphoid tissue which modify the appearance, proportions and relations of some particular part of the tonsil, or there may be diffuse hyperplasia which stretches, obliterates or modifies in various ways the form and appearance of the fetal fossa, with its subdivisions and plicae. Later, at the period of involution, when the lymphoid tissue regresses and its modifying influence is partly removed, one can often recognize in the adult the external relationships and fundamental pattern of the fetal tonsil, provided, of course, that the modifications have not been too extreme and the regression has been as extensive as the original modifying growth.

Finally, in interpreting the morphology of the adult tonsil one must consider the influence of pathologic processes, the results of which often cannot be set apart, except by definition, from the normal structural features.

The gross morphology of the tonsillar fossa in the fetus has been adequately studied and described by a number of investigators, including Hammar,[10] Mosher,[9] Killian,[11] Jurisch,[12] Grünwald[13] and others. It is not our purpose to discuss or to add to this knowledge but merely to explain the discrepancy that exists between our counts of first order crypts and the counts which one would get by enumerating faithfully the openings found on the surface of the adult tonsil. According to our definition, a definitive first order crypt of the palatine tonsil is any hollowed-out, blindly ending, nonglandular epithelial ingrowth which arises from the fossa of the palatine tonsil or from the surface epithelium overlying the lymphoid tissue mass generally regarded as part of the palatine tonsil. A definitive second order crypt is any hollowed-

10. Hammar, J. A.: Bemerkung zu dem Aufsatze von Dr. L. Grünwald: "Die typischen Varianten der Gaumenmandeln und der Mandelgegend," Arch. f. Laryng. u. Rhin. **28**:492, 1914.

11. Killian, J.: Entwicklungsgeschichte, anatomische und klinische Untersuchungen über Mandelbucht und Gaumenmandel, Arch. f. Laryng. u. Rhin. **7**: 167, 1898.

12. Jurisch, A.: Ueber die Morphologie der Zungenwurzel, Anat. Hefte **47**: 35, 1913.

13. Grünwald, L.: Die typischen Varianten der Gaumenmandeln und der Mandelgegend, Arch. f. Laryng. u. Rhin. **28**:179, 1914.

Fig. 9.—Lateral aspect of the crypt system in the left tonsil at 21 years (× 25). The crypts are spaced farther apart than in the child (fig. 6), but their number and order remain unchanged. In the inferior half of the tonsil the crypts have grown in length and thickness (but not in actual complexity), so that this region is now well filled in. Two small cystic crypts are indicated by stippling. The peritonsillar mucous glands (in black) consist of two smaller masses at the superior pole and one long consolidated spiral mass that extends along the anterior border of the tonsil.

out ingrowth arising from a first order crypt, and so on. As the lymphoid tissue increases in amount during infancy, the shallower parts of the tonsillar fossa become obliterated, but the deeper recesses, less easily ironed out by the bulging lymphoid tissue, remain and appear as clefts, pits or fissures. These are usually regarded as crypt mouths, but developmentally they are parts of the original tonsillar fossa. There is no certain way to tell which of these postnatal mouths originate from the tonsillar fossa of the fetus; however, the tonsillar fossa in the fetal stages is commonly deeper in the anterosuperior portion, which becomes incorporated into the superior pole of the tonsil. The models of palatine tonsils at 3, 21 and 65 years show a constantly large pit at the superior tonsillar pole. Previous to the study of the prenatal crypt system this was considered as the mouth of one large complicated crypt. We now prefer to interpret it as a portion of the original tonsillar fossa from which arise numerous first order crypts (fig. 10). Unless such an interpretation is made, the number of first order crypts in the specimens from subjects 3, 21 and 65 years old decreases by two-thirds from the number established as early as the seventh fetal month.

Using the information provided by a study of the serial sections and reconstructions, we shall next recapitulate the life history of the crypt system. During the third month of fetal life, a few small solid epithelial ingrowths arise from the lateral wall of the tonsillar fossa (figs. 3*A* and 4*A*). By the middle of the fourth fetal month numerous processes of this type have appeared (fig. 4*B*) and the formation of crypt mouths is in progress. The larger of these processes are cylindric, but their distal ends are expanded and clublike (figs. 3*A* and 4*B*). This clubbed appearance is caused by the greater growth activity of the distal end of the ingrowth. The formation of the lumen occurs first in this actively growing, distal clubbed portion, while a more proximal, adjacent part lags in development to become a solid, relatively constricted neck (figs. 3*B* and 5). The central epithelial cells undergo partial degeneration and aggregate progressively into a compact epithelial plug, which then occupies the lumen and is especially characteristic of this period of development. This peculiarity of growth results in the creation of numerous cystlike structures, which can now be called epithelial vesicles (figs. 3*C* and 6).

Most of these vesicles are appended to the original epithelial stalk by narrow, solid necks, but the formation of a lumen may occur infrequently in the narrow neck and thus establish communication with the tonsillar fossa (fig. 3*D*). Vesicles of higher orders are formed at the tips and sides of other epithelial ingrowths throughout prenatal development, and these constitute an important and characteristic part of the

crypt system. The epithelial wall of most vesicles undergoes progressive degeneration. Narrowing of the region of the neck, owing to a combination of changes produced by growth and degeneration, results in cutting off of the vesicle (fig. 3*D*). The wall becomes thin; there appear localized areas of vesiculation of epithelial cells and an interruption of epithelial continuity due to invasion by lymphocytes. The vesicle becomes increasingly filled with lymphocytes and epithelial débris. The

Fig. 10.—Part of the crypt system in the left tonsil at 21 years (× 25). The superior third of the model shown in figure 9 is shown from above to demonstrate the curving, antler-like systems of crypts. The two superior masses of peritonsillar mucous glands (in black) and the top of the consolidated spiral gland mass are included.

wall finally breaks down entirely, leaving a space which is filled in, first by the lymphocytes and other free cells of the reticular connective tissue and later by the ingrowth of fixed connective tissue elements, blood vessels, lymphatic vessels and the connective tissue reticulum. Cutting off and degeneration of much of that portion of the prenatal crypt system represented by epithelial vesicles are completed in the early

postnatal months and result in a reduction in the number and complexity of the crypts. Thus, one finds the crypt system less complicated in the early postnatal stage than it was in the late prenatal stage (fig. 7). Most of the vesicles are second to fifth order crypts, seldom first order ones; consequently, their disappearance does not reduce the number of first order crypts (figs. 1 *D* and *E*). Up to the time (about term) when many vesicles are disappearing, there is a gradual increase in the number and order of crypts (fig. 1 *A* to *D*.).

As early as the fifth month certain other epithelial ingrowths begin to appear, which from the first are straight or curved platelike structures (figs. 5 and 6). Often lumen formation first occurs distally in these crypt primordia, but there is little or no tendency for them to become vesicles and undergo degeneration. The development of the lumen usually progresses proximodistad, although distal and proximal formation can occur simultaneously until the lumen is complete. These straight or curved platelike crypts persist and constitute the larger crypts of the tonsil characteristic of childhood and of adult life (figs. 8 and 9). Many smaller ingrowths of variable shape (some solid, some with lumens) comprise other first order crypts and tributary second to fifth order crypts, but the vesicle and the straight or curved platelike crypt are the important types in the prenatal months (fig. 6).

In the preceding paragraphs we have considered the first phase in the development of the crypt system, the end of which is characterized by degeneration of many crypts (mainly epithelial vesicles) shortly after birth. The second phase of development continues well into childhood and results in a more complex system by further growth and branching of the crypts persistent from the prenatal period. The maximum number of crypts is attained during childhood (fig. 2 *A* and *B*), but these crypts later elongate and enlarge by interstitial growth to form a more prominent crypt system; especially is this true in the inferior half, which in the child has relatively stunted crypts. For example, at 21 the tonsil does not have more crypts than at 3 years; yet at 21 it has larger and longer crypts, especially noticeable in the inferior half (figs. 8 and 9). But although the number of first order crypts remains practically constant, many new second order to fifth order branchings arise in the period following the early postnatal destruction of crypts; these are solid at first, but lumens appear later. Vesicles occur infrequently during childhood (figs. 1 *E* and 2 *A*); although typical vesicles can be found, for the most part they are considered to be survivals from the prenatal period. These newly developed crypts assume many shapes; however, among the larger are the characteristic flat or curved platelike variety (figs. 8 and 9). Collectively the large crypts in the superior pole of the tonsil assume an

antler-like appearance (fig. 10). The crypts in the inferior pole are less complex. The growth in thickness of the distal portion of many crypts exceeds that of the region of the mouth; consequently, the latter often appears relatively constricted.

The final phase in the life history of the crypt system is marked by progressive atrophy and degeneration, reminiscent of the late prenatal and the early postnatal period (figs. *2C* and 11). The relatively smaller,

Fig. 11.—Anterolateral aspect of the crypt system in the right tonsil at 65 years (× 25). The atrophy and reduction of the crypts (especially in the inferior half) are obvious. Numerous cysts are indicated by stippled shading. Peritonsillar mucous glands follow the anterior border of the tonsil and extend onto the two poles.

less complex crypts of the inferior half of the tonsil are the last to attain their full growth and the first to degenerate (figs. 8 and 11). Again, vesicles and cysts are formed and the number and order of crypts are reduced. This time, however, the lymphoid tissue shares in

the atrophy and is replaced by the more inert fibrous connective tissue. Ordinarily the walls of the crypts are not in apposition, at least, not in sections,[14] but portions of the crypt may collapse and degenerate, thus leaving cystic a distal dilated portion. Some of the cysts become globular, as though distended by fluid from within. That portion of the crypt system closest to the so-called capsule of the tonsil is the first to degenerate. The first order crypts in the superior pole of the tonsil are spared longest, but the second to fifth order crypts of the superior pole, as well as the smaller crypts characteristic of the inferior tonsillar pole, are the earliest to degenerate.

The prevailing direction of the crypts varies somewhat during the different periods in the life history of the crypt system.[15] The cylindric crypts of early stages, most of which are destined to disappear, point mostly in an inferior direction, but a few extend superiorly (fig. 4*B*). The longer straight or curved platelike crypts, which are late in appearing, are directed antero-inferiorly; the shorter ones point laterally (figs. 5 to 7). As the lymphoid tissue increases in amount, the larger, longer crypts project laterally; their ends tend to curve inward to give the antler-like arrangement shown especially well in the superior third of the adult tonsil (fig. 10). A few crypts of the superior pole point superiorly; only a few, inferiorly. As the tonsil atrophies, the antler-like arrangement of the crypts in the superior portion of the tonsil is lost, and the longer crypts again extend antero-inferiorly and the smaller ones laterally, as in the late prenatal and early postnatal stages.

COMMENT

Comparison with Hammar's Data.—Hammar's [7] description of the developing crypt system is far more complete than those of his predecessors, and it must be reviewed in some detail in connection with our own results. Hammar first considered the fate of the second pouch and the development of the tonsillar fossae and plicae. In a 70 mm. (crown-rump) fetus he then described small, local thickenings on the

14. Barnes [3] stated that the walls of the crypts are normally in apposition. The condition during life is probably similar to that existing in other hollow soft tissue organs, such as the esophagus, intestine and ureter, that is, the walls are normally in apposition unless separated by some liquid or solid substance.

15. Hodenpyl observed that the long axis of the tonsil is nearly vertical when the mouth is open but more horizontal when the mouth is closed. (Hodenpyl, E.: The Anatomy and Physiology of the Faucial Tonsils, with Reference to the Absorption of Infectious Material, Am. J. M. Sc. **101**:257, 1891.) We were able to substantiate this observation. The description given by us of the prevailing direction of the crypts during different stages in the life history of the crypt system assumes that the tonsil is in the more horizontal position, accompanying a closed mouth.

wall of the tonsillar fossa and especially on its superior part. Next in his series is the tonsil of a 110 mm. fetus, of which the crypts and fossa are similar to those in our 100 mm. specimen (3.5 months; fig. 4*A*). Hammar described this tonsil as having fine, solid, stringlike epithelial proliferations. The three superior ingrowths are larger and have swollen ends—an indication that this 110 mm. specimen is slightly more advanced than our 100 mm. stage, which lacks these bulblike endings. The lower two ingrowths are smaller and pointed. Hammar's 145 mm. specimen is described as having numerous finger-like processes, some long and some short. On the ends of many of these processes are epithelial vesicles containing epithelial pearls. Budlike pedunculated branches are also present, and from eight to ten comparatively large portions of the crypt system have become isolated (i. e., cut off from the crypt system). By comparison, our 130 mm. specimen (4.2 months) contains no completely cut-off epithelial balls or masses of epithelium. On the other hand, Hammar's illustration of the 145 mm. stage does not show the long, cylindric type of crypt so characteristic of our 130 mm. specimen (fig. 4*B*). Hammar's 190 mm. specimen possessed many finger-like and clublike ingrowths, most of which contained horny epithelial plugs. Some epithelial balls or vesicles were detached or were in the process of being cut off. The cut-off portions of the crypt system are not so numerous as those in the previous stage. Hammar's models of the crypt systems in the specimens from 235 mm. and 260 mm. fetuses and a full term infant show a gradual increase in the size and number of crypts. His illustrations likewise indicate that the platelike type of crypt is predominant in size and number in the later prenatal stages. The occurrence of isolated epithelial balls is described in all these stages; five such balls in the specimen taken from an infant at full term ranged between 0.4 and 0.9 mm. in diameter. Some of the crypts in the tonsil at term are mentioned as having one or two branches, others none. In general, all of Hammar's observations are in essential agreement with our findings. However, he omitted the important early postnatal stages, which reveal fully the partial destruction of the prenatal crypt system and the simplicity of the system which remains.

Of the postnatal stages, Hammar first described the tonsil of an 8 year old girl. The superior lobe of this tonsil was larger than the inferior lobe. The tonsillar recess had almost disappeared, while the remainder existed as a blind, saclike plate. No plica triangularis was present. The crypt system was characterized as a labyrinth in which some of the component crypts branch. Epithelial vesicles were found in both lobes of the tonsil; these measured from 0.2 to 0.5 mm. in the greatest diameter. Further details concerning this model are not available, owing to the fact that no illustration of it accompanies the article. However, Hammar's short description has a general similarity to our

description of the tonsil of a 3 year old child. The dominance of the superior portion of the tonsil over the inferior part and the reduction of the tonsillar recess are in good agreement. One point of divergence involves the epithelial vesicles, which were not found in our specimen from a 3 year old child. Hammar also modeled the exterior of an adult tonsil (at about 40 years) but not its crypts. His illustrations show the free surface and a view of the lymphoid tissue. The latter was distinctly separated into two lobes, a larger superior and a smaller inferior lobe; these were further subdivided into lobules. A plica supratonsillaris and a plica intratonsillaris were present, but the plica triangularis was rudimentary.

The foregoing statements summarize that part of Hammar's publication dealing with the crypt system of the human palatine tonsil. Comparison of his illustrations of the crypt system in fetal life and childhood with our models helps to establish the important fact that the crypt system is not a disorderly mass of epithelial ingrowths, but instead consists of crypts of definite morphologic types grouped into a fairly predictable arrangement.

Number and Shape of Crypts.—The number of crypts in the human palatine tonsil has been stated variously. According to Barnes,[8] Hellman [16] and Copenhaver,[17] the tonsil has from ten to twenty crypts, but Wilson [18] and Wetzel [19] gave a narrower range, between twelve and fifteen. Piersol [20] mentioned that there are from twelve to eighteen crypts ("follicles"), whereas in a later edition Addison [21] changed this number to from ten to twenty. Jackson [22] placed the number of crypts between ten and thirty. All these values were presumably obtained by counting the openings on the surface of the tonsil. Such an enumeration would include only the larger crypts of the first order, of which the mouths are easily visible. Much more dependable is the method of recon-

16. Hellman, T.: Der lymphatische Rachenring, in von Möllendorff, W.: Handbuch der mikroskopischen Anatomie des Menschen, Berlin, Julius Springer, 1927, vol. 5, pt. 1, p. 244.

17. Copenhaver, W. M., in Bailey, F. R.: Textbook of Histology, ed. 8, Baltimore, William Wood & Company, 1932, p. 281.

18. Wilson, W. J.: A System of Human Anatomy, General and Special, Philadelphia, Blanchard & Lea, 1859, p. 522.

19. Wetzel, G.: Anatomie und Entwicklungsgeschichte der Mundhöhle und des Rachens, in Denker, A., and Kahler, O.: Handbuch der Hals-Nasen-Ohrenheilkunde, Berlin, Julius Springer, 1925, vol. 1.

20. Piersol, G. A.: Textbook of Normal Histology, ed. 2, Philadelphia, J. B. Lippincott Company, 1894, p. 158.

21. Addison, W. H. F., in Piersol, G. A.: Textbook of Normal Histology, ed. 15, Philadelphia, J. B. Lippincott Company, 1932, p. 181.

22. Morris, H.: Human Anatomy, edited by C. M. Jackson, ed. 9, Philadelphia, P. Blakiston's Son & Co., 1933, p. 1221.

struction through which all the smaller first order crypts as well as crypts of higher orders (branchings of first order crypts) can be accurately counted. The graphs in figures 1 and 2 summarize the results concerning the number and order of crypts existing during various stages of development. It is interesting to note that the number of first order crypts is fairly constant in the models of tonsils from subjects at term, 1 month postnatal, 3 years and 21 years. By contrast, the higher orders are less constant. This indicates that the second to fifth order crypts represent the later formed, growing part of the crypt system in postnatal years. In the present series of models the number of first order crypts increases gradually up to term and then remains constant until atrophic changes set in. The number of second and third order crypts likewise increases gradually up to term, but it decreases markedly in the early postnatal period owing to degenerative changes and then reaches a new high level during childhood. Thereafter the number of these crypts is reasonably constant until the final regressive changes begin. The number of fourth and fifth order crypts similarly reaches two peaks, the first (lower) maximum at term and the second maximum some time during childhood, although additional studies would be necessary to fix the exact time for this. In the present series of models there were no fourth or fifth order crypts in either the 1 month postnatal or the 65 year stage. Apparently during the two periods of degeneration in the history of the crypt system the last crypts to be formed are among the first to disappear.

Concerning the shape of the crypts Barnes [3] said: "The crypts may be single and without noticeable change in calibre throughout their length, or they may be extensively branched and their calibre much greater below their surface than their faucial openings would indicate. Their walls are normally in apposition yet the accumulation of cellular debris within them is so frequent that a mild degree of irregular pocketing that results cannot be considered abnormal."

The reader has already been informed how a more exact conception of the shape of crypts can be obtained by reconstruction methods, while the details of these matters have been adequately presented in earlier paragraphs. In addition, it should be emphasized here that the shape of a crypt can be modified by its contents or by the surrounding tissues. We might theoretically assume the latter factor to be influential at the time of lymphoid hyperplasia, and it undoubtedly does then exert some influence. However, prospective crypts in the models of tonsils from a 6 month fetus and from an infant born at full term are platelike from the beginning, even before the formation of a lumen. This implies that the tissue surrounding a crypt exerts only a secondary effect on its shape. Moreover, during the growth of the crypts their contents consist of epithelial plugs, composed of dead, desquamated epithelial cells and

of lymphocytes which have invaded the epithelial wall and reached the lumen. The shape and size of the epithelial plug is dependent on the proportions of the original epithelial invagination which it fills as a cast. Hence, one must conclude that the epithelium (developing, doubtless, along a definite hereditary pattern) is of primary importance in determining the size and shape of a crypt. This does not imply that other factors are without effect. As a matter of fact, pathologic processes probably modify the size and shape of crypts, as do the changes accompanying atrophy. By way of illustration, it cannot be questioned that the crypt system of the specimen from a 65 year old person has been thus modified through involution. The cysts already described for this specimen clearly resulted from such changes.

Anastomosis of crypts is not frequent; nevertheless, two examples were observed, one in the specimen from a 3 year old child and one in the specimen from a person 21 years old. Such anastomosis of crypts in the palatine tonsil has not to our knowledge been reported previously. Since anastomoses were not observed in any of the prenatal specimens, we are not prepared to decide whether they are products of normal developmental fusion or a sequel to pathologic changes.

The approximate surface area represented by the crypt epithelium of the tonsil at 21 years was determined. The total surface area is 295 square centimeters (45.7 square inches). Two such tonsils would represent 590 square centimeters (91.4 square inches); hence a bilateral tonsillectomy represents the removal of over ½ square foot of epithelial surface. For comparison, it was determined that the total superficial area of one pharynx, exclusive of its crypts, is only 44.8 square centimeters (6.9 square inches).

Relation of Ducts to Crypts.—Bickel,[23] Schmidt[24] and Toldt[25] expressed the opinion that the mouths of mucous ducts open into the crypts. Levinstein,[1] Renn[26] and Piffl[27] modified this view by stating

23. Bickel, G.: Ueber die Ausdehnung und den Zusammenhang des lymphatischen Gewebes in der Rachengegend, Arch. f. path. Anat. u. Physiol. **97**:340, 1884.

24. Schmidt, F. T.: Das follikuläre Drüsengewebe der Schleimhaut der Mundhöhle und des Schlundes bei dem Menschen und den Säugetieren, Ztschr. f. wissensch. Zool. **13**:221, 1863.

25. Toldt, C.: Lehrbuch der Gewebelehre, ed. 2, Stuttgart, Ferdinand Enke, 1884, p. 427.

26. Renn, P.: Zur Funktionsfrage der Gaumenmandel: Cytodiagnostische und histopathologische Untersuchungen, Beitr. z. path. Anat. u. z. allg. Path. **53**:1, 1912.

27. Piffl, O.: Der Waldeyersche Rachenring und der Organisms, Med. Klin. **9**:286, 1913.

that only exceptionally does this occur, while Ellenberger and Illing [28] also doubted the conclusions of Bickel, Schmidt and Toldt. Finally Schlemmer [29] studied many palatine tonsils sectioned serially and did not find a single instance in which ducts emptied into crypts; these observations are in essential agreement with our own.

If the relationship of the ducts to the crypt system throughout the entire life span of the tonsil is considered, it will be easier to interpret this problem with greater accuracy. As previously stated, the reason ducts are rarely found draining into crypts is that they establish themselves before the crypts appear as later independent ingrowths. The occasional finding of a duct opening into a crypt can be explained in several ways. First, a duct arising originally from the fetal tonsillar fossa might be transferred into the mouth of a crypt; this would accompany the probable incorporation of parts of the fetal fossa into what then must be considered as parts of the crypt system. This seemingly explains why the few ducts found by us connecting with the crypt system emptied only into the mouth of a crypt. Again, a duct opening originally on the tonsillar surface near the crypt might be incorporated into its altered mouth owing to the shrinking of the mucous membrane which accompanies the fibrotic invasion of the tonsillar substance during atrophy. Another sort of condition, which can easily lead to misinterpretations, is the existence of the dilated mouths of ducts which are often surrounded by lymphoid tissue and can then be mistaken for true crypts.

We may conclude, therefore, that the ducts of mucous glands rarely open into crypts, but when they do, it is probably as the result of secondary changes. Even then a duct does not open into the distal, blind portion of the crypt and consequently could not wash out the collected débris, as sometimes has been implied. Kahler [5] has emphasized the clinical importance of this physiologic deficiency. We believe that the evidence brought to light in the present investigation on the essential separateness of glands and crypts, combined with that of Schlemmer,[29] already noted, definitely establishes the course and relationships of the peritonsillar mucous ducts.

Relation of Crypts to Infection.—Grünwald [13] has commented on the frequency of supratonsillar infections. The fact that the crypts are

28. Ellenberger, W., and Illing, G.: Die Mandeln (Tonsillen) der Mundhöhle und das Vorkommen des zytoblastischen Gewebes dasselbst, in Ellenberger, W., and Baum, H.: Handbuch der vergleichenden Anatomie der Hausthiere, Berlin, A. Hirschwald, 1911, vol. 3, p. 81.

29. Schlemmer, F.: Die chronische Tonsillitis und ihre Behandlung: Anatomische und physiologische Vorbemerkungen, Ztschr. f. Hals-, Nasen- u. Ohrenh. **4**: 405, 1923.

longer, more complicated and more numerous in the superior part of the tonsil might have some bearing on the greater frequency of infection about the supratonsillar fossa. Barnes [8] mentioned that the crypts opening behind the plica triangularis drain poorly, as do those emptying into the supratonsillar fossa, because the latter extend obliquely downward and outward. In the models made from the tonsils of persons of 3, 21 and 65 years the crypts in the superior pole of the tonsil pointed laterally for the most part, while some in the models of tonsils from subjects of 3 and 21 years pointed superiorly (figs. 8, 9 and 11). However, even granting that the crypts in the superior poles of some tonsils point downward does not of itself necessarily imply that these crypts are poorly drained, since Schlemmer,[29] Gott [30] and Trotter [31] have urged that the crypts empty as a result of contraction of the peritonsillar muscles during swallowing. It is true that the contracting action of these muscles undoubtedly helps to evacuate the crypts, but, in spite of this tendency, examination of crypts often reveals much cellular débris, bacteria and food particles. Furthermore, the collected débris cannot readily be squeezed past the narrow necks of many crypts. Lexer [32] and Grober [33] even expressed the belief that the relaxation after swallowing causes the crypts to suck in bacteria and foreign particles. In order to correlate the idea of Gott, Schlemmer and Trotter with that of Lexer and Grober, one must think of the tonsil as being somewhat like a rubber syringe; if when it is squeezed some of its contents are given up, then when the pressure is released bacteria, food particles and other cellular débris near the tonsillar crypts must be taken up by virtue of the resulting aspiration. Nevertheless, there must be at best a high degree of inefficiency in the practical operation of this mechanism as a whole; this is due both to anatomic constrictions and to the tendency of the contents of a complex crypt system to impact at the bottle neck region of the main crypt, which is not necessarily of greater caliber than the tributary ones.

Time of Atrophy.—The time when the palatine tonsil begins to atrophy is probably subject to great variation. According to Fox,[34]

30. Gott, T.: Die Speichelkörperchen, Internat. Monatschr. f. Anat. u. Physiol. **23**:378, 1906.

31. Trotter, H. A.: The Function of the Muscular Attachments of the Tonsil, Ann. Otol., Rhin. & Laryng. **38**:825, 1929.

32. Lexer, E.: Die Schleimhaut des Rachens als Eingangspforte pyogener Infektionen, Arch. f. klin. Chir. **54**:736, 1897.

33. Grober, J.: Die Tonsillen als Eintrittspforten für Krankheitserreger, besonders für den Tuberkelbazillus, Klin. Jahrb. **14**:547, 1905.

34. Fox, R. H.: The Functions of the Tonsils, J. Anat. & Physiol. **20**:559, 1886.

Spicer,[35] Hett and Butterfield [36] and Hett,[37] the palatine tonsils are fully developed in childhood, and regressive changes start in this period. Hett and Butterfield stated that the more internal portions of the tonsil show initial atrophic changes in the fourth and fifth years of life, whereas the more superficial portions are not similarly involved at that time. Later, at about the fourteenth year, the atrophy is more general. Between the ages of 20 and 30 the plica triangularis, which is often infiltrated with lymphoid tissue, becomes the most prominent part of the tonsil. Hodenpyl [15] likewise concluded that the absolute size of the tonsil is greatest in childhood, whereas in advanced age the tonsil consists mostly of fibrous connective tissue.

On the other hand, Kniaschetsky [38] reported that the tonsil in the 1 year old child is 3.5 times larger than at birth; at 5 years, 3.5 times larger than at 1 year, and at 20 years, 3.5 times larger than at 5 years. Similarly, Kniaschetsky,[38] Kayser [39] and Mathies [40] all set the period of size involution later than did Hett and Butterfield.[36] Mathies reported that the tonsil remains well developed during puberty and retains its size for some years thereafter, finally undergoing degeneration during senescence. According to Brieger,[41] the hypertrophic tonsil of childhood should be looked on as a normal structure, while the following involution is but limited. In this regard our reconstructions indicate that progressive growth continues throughout childhood and that the final organization attained is still present in the adult. These observations would tend to militate against the belief in an early regression, as advanced by Hett and Butterfield, and to corroborate the general conclusions of their critics.

CONCLUSIONS

1. The crypts of the human palatine tonsil begin to appear during the third fetal month as solid ingrowths from the epithelial wall of the

35. Spicer, S.: The Tonsils (Faucial, Lingual, Pharyngeal and Discrete): Their Functions and Relation to Affections of the Nose and Throat, Lancet **2**: 805, 1888.

36. Hett, S., and Butterfield, H. G.: The Anatomy of the Palatine Tonsils, J. Anat. & Physiol. **44**:35, 1910.

37. Hett. S.: The Anatomy and Comparative Anatomy of the Palatine Tonsil and Its Rôle in the Economy of Man, Brit. M. J. **2**:743, 1913.

38. Kniaschetsky: Ueber die Tonsillen der Kinder, Inaug. Dissert., St. Petersburg, 1899.

39. Kayser, R.: Die Krankheiten des lymphatischen Rachenringes, in Bergengrün, P.; von Bergmann, E., and others: Handbuch der Laryngologie und Rhinologie, Vienna, A. Hölder, 1899, vol. 2, p. 487.

40. Mathies, W.: Ueber den Entwicklungsgang des Waldeyer'schen Rachenringes, Beitr. z. path. Anat. u. z. allg. Path. **94**:389, 1935.

41. Brieger, O.: Beiträge zur Pathologie der Rachenmandel: I. Zur Genese der Rachenmandelhyperplasie, Arch. f. Laryng. u. Rhin. **12**:254, 1901.

tonsillar fossa. Subsequently these epithelial processes grow, branch and canalize, although the end of such progressive development is not reached until late childhood.

2. The formation of a lumen usually takes place first in the distal, most rapidly growing part of an epithelial ingrowth. However, simultaneous formation of the proximal and the distal portion of the lumen occurs also.

3. A first phase in the development of the crypt system is characterized by a peculiarity of growth owing to which many of the epithelial ingrowths form epithelial vesicles (cystic crypts). The majority of these epithelial vesicles, attached to the permanent crypts by narrow necks (most necks are solid, but some have lumens), undergo progressive degeneration and disappear shortly after birth. However, it is possible that some persist as the residual vesicles (cysts) of childhood and adult life.

4. A second phase in the growth of the crypt system, which also begins in the early prenatal months, is marked by the appearance of new first order crypts, by the further growth of similar crypts (straight or curved platelike type) of the first and second order which escape destruction during the first phase and by the formation of many new second to fifth order crypts which increase in number gradually up to the time when the full quota is obtained (some time during early childhood).

5. Although the maximum number of crypts is reached during childhood, these later elongate and enlarge by interstitial growth to form the definitive crypt system. In our series of models the number of first order crypts remains relatively constant throughout childhood and even until the onset of tonsillar senescence.

6. A greater variety of shapes is found accompanying the increase in number and complexity of the crypts than occurs in earlier crypt systems. The shape of the original epithelial ingrowth is the principal factor that determines the shape of the crypt. Some crypts are budlike, some irregularly cylindric and some long, narrow and sinuous. But the curved or flat platelike type is predominant in number and size. Many of the large first and second order crypts have constricted necks. Anastomosing crypts are of great rarity but have been demonstrated for the first time.

7. The size and complexity of most crypts in the superior half of the tonsil are greater than in the inferior half. This domination persists from fetal life, at which time the formation of the superior part of the tonsil occurs in advance of that of the inferior portion.

8. From the beginning of the development of crypts into childhood, the crypts of the inferior half of the tonsil are relatively short and small.

The completion of growth inferiorly, so that this region is filled in equally with the superior half, is the most outstanding advance of the final developmental period, which produces the definitive tonsil.

9. The final phase in the life history of the adult crypt system is marked by progressive atrophy and degeneration, reminiscent of the late prenatal and early postnatal period. The less complex portion of the crypt system of the inferior half of the tonsil is not only the last to attain full growth but the first to degenerate. Again vesicles and cysts appear as by-products, and the number and order of crypts are reduced. Atrophy of lymphoid tissue and compensatory formation of fibrous tissue accompany the degeneration of the crypt system.

10. Ducts of the peritonsillar mucous glands establish themselves before the crypt system has attained any prominence. This explains why the ducts are so rarely found emptying into crypts and then always near the mouth. Connection with crypts is the result of secondary incorporation. Dilated mouths of ducts surrounded by lymphoid tissue sometimes simulate simple crypts into which ducts empty, but these should not be confused with true crypts.

11. The approximate area of the epithelial lining of the adult crypt system of one tonsil was calculated to be 46 square inches (295 square centimeters), whereas the exposed surface area of an entire pharynx was only 7 square inches (45 square centimeters).

12. Any tendency to empty the tonsillar crypts through natural or artificial means must necessarily be highly inefficient owing to anatomic constrictions and the tendency of the contents of a complex convergent system to impact at the bottle neck region of the main crypt. Such plugging is further enhanced by the circumstance that the main drainage channel is often smaller than its tributaries.

TONSILLECTOMY AS A CURE FOR PERITONSILLAR ABSCESS

WITH CASE REPORTS

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A review of the literature shows that comparatively little has been written by American authors advocating complete removal of the tonsil for peritonsillar abscess. Many laryngologists in foreign countries carry out this procedure as a routine, and in general they agree that such a procedure is rational and is not attended by the complications and dangers that American physicians have been taught accompany it.

Tato said that tonsillectomy in the acute stage of peritonsillar abscess is a procedure free from dangers which have been attributed to it on the basis of dogmatic prejudice.

Link reported a series of about 280 cases, with a percentage of complications no greater than that for tonsillectomy under any other conditions.

Peritonsillar abscess is a condition with which every laryngologist has to deal, and results obtained by the ordinary method of treatment are often disappointing, to say the least. The patients suffer a great deal and incision and drainage of the abscess frequently do not give much relief at the time and often have to be repeated in the following two or three days.

By a tonsillectomy performed at the time of the formation of the abscess, the patient is immediately relieved of distressing pain, which is the outstanding symptom of this disease. In addition, the patients are often very toxic, and their general condition shows evidence of having suffered as the result of insufficient ingestion of food and water. One of these patients twenty-four hours after a tonsillectomy has been performed is a gratifying sight. The general condition is much improved; the patient has been able to take at least some nourishment, and in many instances is almost completely free from pain. The fever has begun to subside; the swelling in the palate and the pharyngeal wall has become reduced, and swallowing is no longer a difficult procedure.

Patients who have had experience with previous attacks of quinsy often make the statement: "This was the easiest attack of quinsy I ever had."

This is not a new procedure, but most laryngologists have hesitated to adopt it. The consensus seems to be one of condemning the pro-

cedure without so much as a single trial. There has been little written condemning the procedure after the author has given it a fair trial. Removal of the tonsil at the time of formation of the abscess seems to me to be a perfectly rational surgical procedure.

The tonsil is surrounded on three sides by muscle tissue. The bed in which the tonsil lies is bounded anteriorly by the palatoglossus muscle, posteriorly by the palatopharyngeus muscle and externally by the superior constrictor muscle of the pharynx. It is attached by more or less loose areolar tissue to the aponeurotic layer covering the superior constrictor muscle. The tonsil is more easily separated from its bed in the upper half, and it is in this region that peritonsillar abscess most frequently is formed. Incision and drainage are often incomplete; the incision has a tendency to close, making reopening necessary at intervals in the next two or three days. In the formation of the peritonsillar abscess there is marked infiltration of the muscles which ordinarily partially surround the tonsil. This is an effort on the part of the body to localize the abscess, and as a result of this infiltration and subsequent resolution with the formation of pus, the tonsil is ordinarily pushed toward the midline. In removal of the tonsil, the protective wall of infiltration in the tissues surrounding the tonsil is not disturbed. The tonsil itself is not involved in the protective mechanism set up by the body to prevent the spread of the infection. It may be considered as a wall which completes the closure of the cavity made in the process of formation of the abscess. With removal of this wall, one side forming the cavity has been taken out; drainage is complete, and, if the operator is careful, the area of induration which prevents the spread of infection is not disturbed by tonsillectomy any more than it is by simple incision. This is attested by the fact that uniformly good results are obtained by physicians who practice and advocate this procedure.

TECHNIC OF OPERATION

As a rule, general anesthesia is preferable. It enables the operator to obtain a better exposure than is possible with the area under a local anesthetic, because the patients have difficulty in opening their mouths. With the aid of the suction machine and with the patient in the recumbent position, there is less likelihood of aspiration of pus. In my series of twenty-one cases, local anesthesia was used once, n-methylcyclohexenylmethylmalonylurea once, tribromethanol in amylene hydrate once and nitrous oxide induction followed by ether in the remaining eighteen cases.

An incision is made just through the mucosa, following the anterior pillar and down the posterior pillar. Then, with slight traction on the tonsil in the upper portion, dissection is started in an endeavor to free a portion of the upper pole before the abscess is ruptured. Then, with a suction tip following the knife, the incision is made into the

Synopsis of Cases in Which Tonsillectomy Was Performed for Peritonsillar Abscess

No.	Name	Age	Examination of Throat	Pre-operative Temperature, F.	Highest Postoperative Temperature		Anesthetic
					First Day	Second Day	
1	J. S.	27	Abscess on right; tonsillitis 4 days previously	100.0	98.6	99.0	Nitrous oxide-ether
2	R. T.	26	Abscess on right; acute follicular tonsillitis for 4 days	98.4	99.8	99.4	Local
3	T. T.	39	Recurrent abscess on right; also abscess on left 2 weeks previously	100.0	98.6	99.0	Tribromethanol in amylene hydrate
4	M. B.	35	Abscess on left; with acute tonsillitis on right	102.4	99.0	100.6	Nitrous oxide-ether
5	B. H.	23	Abscess on right; acute follicular tonsillitis 1 week previously	99.0	99.0	98.6	Nitrous oxide-ether
6	H. S.	28	Abscess on right; acute tonsillitis 5 days previously on both sides; quinsy 2 years previously	100.6	98.0	99.0	Nitrous oxide-ether
7	V. F.	20	Abscess on left	98.6	99.0	101.6	Nitrous oxide-ether
8	E. P.	36	Recurrent quinsy on left	99.6	97.4	100.4	Nitrous oxide-ether
9	E. C.	40	Acute tonsillitis and abscess on right	101.0	100.6	98.6	Nitrous oxide-ether
10	A. M.	40	Abscess on left; buried tonsil tag	99.6	99.0	99.8	n-methylcyclohexenylmethylmalonylurea
11	G. S.	26	Abscess on left; acute inflammation of tonsil on left 3 days previously	100.0	99.6	99.0	Nitrous oxide-ether
12	B. L.	28	Abscess on left; tonsil tags	99.4	99.0	101.0	Nitrous oxide-ether
13	J. M.	13	Abscess on right; tonsil tag	100.6	98.0	98.0	Nitrous oxide-ether
14	B. H.	40	Abscess on left; tonsil tag; had 3 operations for removal of tags	99.6	98.6	98.0	Nitrous oxide-ether
15	R. Y.	56	Abscess on right; acute tonsillitis and abscess on left 4 months previously	100.0	99.0	100.0	Nitrous oxide-ether
16	L. B.	50	Abscess on left; tonsil tags; tonsillectomy twice previously; white blood cells, 15,600	98.4	99.6	99.6	Nitrous oxide-ether
17	F. A.	35	Abscess on right; much infiltration on left	101.0	98.4	98.2	Nitrous oxide-ether
18	S. S.	29	Abscess on right	100.6	99.6	99.0	Nitrous oxide-ether
19	M. G.	40	Abscess on left; acute tonsillitis 3 days previously; white blood cells, 12,850	102.4	101.0	100.6	Nitrous oxide-ether
20	G. S.	36	Recurrent abscess on left	99.4	98.6	99.0	Nitrous oxide-ether
21	H. S.	50	Abscess on right; also abscess on left found at operation	99.4	100.4	98.6	Nitrous oxide-ether

abscess cavity and the abscess is drained completely with the suction tip. This relieves tension immediately, and with the upper pole practically free, the tonsil is easily lifted from its bed; with a small amount of dissection, it is loosened from the anterior and posterior pillars, a snare is slipped over the mass and the tonsil is removed with little difficulty. Occasionally, there is rather free bleeding from the pillars or in parts of the fossa. This is a general oozing, and hemostasis is difficult to obtain with hemostats. By the use of an electrocoagulation machine which has previously been set up, this bleeding is immediately controlled with a minimum amount of trauma, and in cases in which this has been used, patients seem to have somewhat less postoperative pain. After this procedure is completed and all bleeding is stopped, the other tonsil is removed. This makes it unnecessary for the patient to undergo any further surgical treatment at a later date.

Recovery is rapid, and patients take nourishment more easily and sooner after tonsillectomy than they do after incision and drainage. Complete healing is obtained in approximately the same length of time as after tonsillectomy done under ordinary circumstances.

One case demonstrated the possibility of encountering great difficulty in incision and drainage. The abscess was situated so that incision through the usual site would have missed it. After removal of the tonsil, the wall of the fossa bulged medially and fluctuation was felt. Incision was made in the fossa near its lower part, and pus was evacuated. The patient was immediately relieved and made a rapid recovery. Had this tonsil been allowed to remain, with incision employed, it seems probable that considerable difficulty might have been encountered.

Two patients showed the value of tonsillectomy over incision and drainage of the abscess.

T. S. S., a man aged 39, when first examined, on Nov. 30, 1933, had a peritonsillar abscess on the right side. Incision and drainage were done. He was again treated on Dec. 8, 1933, for a peritonsillar abscess on the left side. Incision and drainage were done. On Dec. 23, 1933, he had a recurrent peritonsillar abscess on the right. At that time, a tonsillectomy was done. He made an uneventful recovery. Had tonsillectomy been done at the time when he was first seen, I believe that he would have been spared considerable expense and loss of time.

Mrs. E. P., aged 36, was seen on Jan. 12, 1935. She had been under the care of the family physician for about ten days, in which time he had opened a peritonsillar abscess on the left side two different times, with improvement after each incision. The abscess was recurring, and the patient was uncomfortable and had lost considerable weight owing to the inability to take nourishment. Tonsillectomy was done, and she made a rapid uneventful recovery.

CONCLUSIONS

Twenty-one cases, the patients ranging in age from 13 to 56 years, are summarized in which tonsillectomy has been performed for quinsy, thus adding to the number already reported in the literature.

There were no complications in any case, and each patient showed immediate improvement.

My experience and recommendations coincide with those reported by other authors. A bibliography covering this subject for the past ten years is included.

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FURTHER EXPERIENCES WITH SUPPURATION OF THE PETROUS PYRAMID

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The basic work of Eagleton, Kopetzky and Almour, Profant and others has established suppuration of the petrous pyramid as a clinical entity. It remains for time and experience to make this condition better understood. For this reason future papers will serve to define in greater detail what is already known or will deal with special phases of the subject. As evidence of this, mention might be made of a recent paper by Eagleton which deals with osteomyelitis of the inferior aspect of the petrous pyramid.

We believe with Eagleton that a majority of infections of the petrous pyramid heal spontaneously, that a small group end in localized formation of abscesses which are healed by well directed treatment and that a still smaller group are caused by progressive vascular involvement in the form of thrombophlebitis, which is invariably fatal. Those which heal spontaneously would present no special problem if one could foretell their favorable outcome. Those which form a localized abscess or empyema are the special and most serious concern of the otolaryngologist, for it is within his province to recognize and to cure them. In other words, early recognition and adequate and properly directed surgical treatment should save all patients of this group.

Most of the patients with otitis media or mastoiditis which terminates in meningitis are considered as having had an intermediate petrous infection. The meningitis continues to tax the ingenuity of physicians, despite the extensive surgical treatment which has been advocated by Eagleton, Neumann, Kopetzky and others and which is being practiced by many. However, a majority of the patients with meningitis which is caused by direct extension of the infectious process through the anterior surface of the petrous pyramid or through its posterior wall or apex are being saved because of a better understanding of the pathologic process and because of timely intervention. Even when such intervention reaches the optimal, there will continue to be fatalities, for there will always be cases in which the area of disease cannot be

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localized. There is no reason why one should not hope to save all those persons who have empyema of the apex long before signs of meningeal irritation develop.

The classification according to clinical course and outcome would justify the division of the cases requiring surgical intervention into two groups from the standpoint of the pathologic process and its end-result in the bone when the patient is seen. First, those cases which constitute the larger group of instances of empyema of the entire apex or part of it, and, second, those in which empyema is preceded by osteomyelitis. In each group, however, the end-result is the same, namely, empyema of the apex. There are a few exceptions, which will be mentioned later. In the first group one finds the well pneumatized bones with large cavities in the apex. In the second group pneumatization is much less advanced; the bone is diploic and more solid. These types are well illustrated in the roentgen studies of involvement of the petrous pyramid.

In a majority of instances empyema of the apex is recognized by a break in the continuity of the roof or the superior line of the apex. This is so when the roof of the cavity in the apex is part of the anterior surface of the petrous pyramid. Occasionally the upper half of the apical area is solid while its lowermost portion is cellular and constitutes the cavity. Osteomyelitis may be the only type of infection for some time, until it finally gives way to the empyema which it has produced. Many bones have such fine structure in the tracts which lead to the apex from the middle ear or the mastoid that only osteomyelitis can carry the infection there. Empyema which is preceded by osteomyelitis is in a majority of instances an infection of the inferior aspect. In these cases the horizontal portion of the internal carotid artery lies on a shelf of bone which is thick and cancellous. This area may become infected by means of a tract of cells which begins either between the cochlea and the carotid artery beneath the orifice of the eustachian tube (cochlear carotid angle) or beneath the posterior semicircular canal. That empyema of the apex follows osteitis or osteomyelitis has been proved by every case in which the condition has been cured by one surgical procedure or another. In these cases pus was evacuated after a tract of diseased cells was traced into the apex, after the apical area was exposed and drained or after a nasopharyngeal abscess had formed, which ruptured spontaneously or was evacuated.

Only when gross pathways of infection are detectable can one hope to have an aid to the future management of the condition, for it is by gross means that one attacks such an infection. It is for this reason that histologic study of previously diseased petrous bones has a limited application and value. It must be borne in mind that the damage in a bone removed after a fatal infection is more extensive than that which

is encountered when life-saving surgical procedures are performed. Therefore, the value of the histopathologic observations in these cases is limited.

Last year we observed a child who after a mastoidectomy had a profusely discharging ear, a slightly elevated temperature and severe transient headache. The pulse rate was elevated, and she was not doing well. Roentgen study in the Stenver position revealed nothing significant. A film was not taken in the mentovertical, or base, position. At operation a fistulous tract was found just below the tubal orifice between the cochlea and the carotid artery. A fair amount of pus was evacuated. When reviewing this case later we felt that a film taken in the base position would have demonstrated an abscess in the inferior portion of the petrous apex. It was resolved that in the future we would resort to the base position whenever the roentgenogram taken in the Stenver position showed no abnormality. An opportunity to do this came in case 6, in which we were able to demonstrate the presence of an infection of the inferior aspect of the apical area before rupture into the nasopharynx occurred (fig. 4). The film which had been taken in the Stenver position showed no involvement, while that taken in the base position showed evidence of changes. Two days later an abscess formed in the roof of the nasopharynx.

We believe that roentgen study in these two positions constitutes the only accurate and dependable diagnostic method available for ascertaining the presence of an infection of the inferior aspect of the petrous apex. The finding of a tract of softened bone in the hypotympanic or sublabyrinthine area might in some cases indicate the same.

We can also state that when a roentgenogram taken in the Stenver position shows a break in the continuity of the roof of the apex, one is dealing with a collection of pus in the apical cavity. The loss of continuity of the roof indicates that the temporal lobe of the brain is corking the abscess cavity. A review of our films and of the roentgen studies published by others would indicate that this is the most frequent type of involvement of the petrous apex. The only exception to this is the case in which the roentgenogram made in the Stenver position shows an extension of the shadow of the apex into the space above. In such cases a granuloma with or without pus will be found to exist in the apical area. Because in so many cases empyema of the apex erodes through the roof or the anterior surface, the suggestion which Clarence Smith made several years ago would seem to have some value. He advocated the elevation of the temporal lobe and the placement of a strip of rubber dam down to the apex, so that if the infectious process erodes through, the pus will be drained off before it can affect the overlying dura.

We believe that the roentgen study is the most important and the most definite single factor in the diagnosis and management of suppu-

ration of the petrous pyramid. There are four types of significant roentgen findings in these cases:

1. If the roentgenogram taken in the Stenver position and that taken in the mentovertical, or base, position both show evidence of an abscess cavity, it means a break through the roof.

2. If the roentgenogram taken in the Stenver position and that taken in the mentovertical, or base, position both show evidence of an abscess cavity, with extension of the shadow of the apex above the line of its roof, it means that a granuloma is present, with or without pus.

3. If the roentgenogram taken in the Stenver position shows no evidence of abscess and that taken in the mentovertical, or base, position shows evidence of involvement, it indicates a localized abscess of the inferior aspect, with or without a break into the nasopharynx.

4. If the roentgenogram taken in the Stenver position and that taken in the mentovertical, or base, position show no evidence of involvement except slight haziness of the entire petrous pyramid, it indicates no destruction of bone but a vascular spread of the disease.

The first type is well illustrated by our case 3, in which there was most striking evidence of empyema of the apical area. This was so pronounced that we did not search for diseased tracts but elevated the temporosphenoid lobe of the brain and evacuated about ½ ounce (15 cc.) of pus (fig. 2).

We have had two cases with roentgen findings of the second type, in which a granuloma existed in the apical area; in one instance there was only a granuloma (case 4), while in the other there was pus in addition. This would appear to be a dangerous type of lesion; both our patients died (fig. 3).

The third type is well illustrated by case 6, in which two days after such roentgen findings the process eroded into the nasopharynx (figs. 6, 7 and 8).

W. M., a youth of 19, presented roentgenologic changes of type 4. Three operations were unsuccessful in combating the disease in the temporal bone. He had severe headache from the start. A localized epidural abscess, softened tracts of cellular bone or an abscess of the apex was not found. Postmortem examination revealed no local area of disease in the bone from which a spread to the meninges had occurred.

We have been impressed with the frequency of the presence of granuloma in the middle ear in our cases of involvement of the petrous pyramid. The granuloma protrudes through the perforation in the drum membrane. In most of the cases in which there is an increase in the discharge from the middle ear with the onset of symptoms of involvement of the petrous pyramid inspection reveals the presence of such

a granuloma. Such a granuloma may make its appearance without an increase in the quantity of discharge, but it is usually associated with exudate in the middle ear. The granuloma may make its appearance quickly, coming on only a few hours after a previous examination which did not disclose such a condition. The protrusion, which is at first slight, becomes prominent if the infection in the petrous pyramid advances and may almost completely fill the fundus of the aural canal. Of interest also is the fact that the granuloma disappears within a short time after the apex is completely drained. The granuloma will persist if the apex is not completely drained.

REPORT OF CASES

We wish to add the following cases to those previously reported:

CASE 1.—A child 7 years of age was admitted to the hospital on June 8, 1936, with pain in the right ear. Her previous history was not significant. On the seventeenth day of an attack of measles earache developed on the left, which resolved within a few days. The day after the earache began on the left side she experienced earache on the right, which continued for several days. The condition of the right ear became worse, so that a mastoidectomy was necessary. During the six days following the operation the temperature fluctuated between 99 and 105 F. On the seventh day she complained of severe occipital headache. A granuloma was seen to protrude through the drum membrane while the postauricular wound continued to discharge profusely. A week later a roentgenogram taken in the Stenver position showed no involvement. A film was not made in the base position.

Because of the clinical course a second mastoidectomy, which consisted of a thorough exploration, was carried out. Part of the bone constituting the tegmen of the mastoid and the plate over the lateral sinus was found to be necrotic. Despite the removal of this diseased bone the temperature continued high. Blood cultures repeatedly gave negative results. The postauricular wound continued to drain profusely. Eight days later a radical mastoidectomy was performed. In the course of this operation a tract of softened bone was found, which led into the apex from a point below the orifice of the eustachian tube between the cochlea and the internal carotid artery. About 3 drachms (11 cc.) of pus was evacuated. Some pus was also found in the soft tissues of the neck directly under the aural canal. After this the patient made an uneventful recovery.

Summary

Date	Clinical Symptoms	Roentgen Findings	Operation and Findings	Comment
June 10	.....	.....	Mastoidectomy	
June 27	Occipital pain; temperature 99-105 F. for past 17 days			
July 4	.....	Stenver position, no involvement	Exploration; necrosis of tegmen mastoidei and sinus plate	
July 12	.....	.....	Mastoidectomy; fistulous tract into apex between cochlea and carotid artery; pus evacuated; pus in soft tissue	Recovery uneventful

Comment.—In this case osteomyelitis of the inferior aspect of the petrous pyramid progressed to localized empyema. An elevated temperature and pulse rate, with occipital headache which lasted but one day, were significant symptoms. Three operations were performed, the last a radical mastoidectomy which disclosed a fistulous tract into the apex in the cochlear carotid region. Pus found its way along the inferior aspect of the petrous pyramid to a point below the aural canal. A roentgenogram taken in the Stenver position showed no involvement.

Fig. 1 (case 1).—Roentgenogram of the right petrous area taken after operation, showing a fine probe placed through the fistula created at operation between the internal carotid artery and the cochlea below the orifice of the eustachian tube.

A plate had not been taken in the base position; had this been done we would have had evidence of an inferiorly placed infection (fig. 1).

Case 2.—A girl 8 years of age was admitted to the hospital on May 8, 1936. A double mastoidectomy had been performed in February. Since that time both ears had discharged at intervals. During the two weeks before examination she had complained of headache on the right side, more severe in the frontal region. The left middle ear had healed while the mastoid wound was still draining profusely; the right middle ear was also dry, and the postauricular wound was almost healed. Before her admission to the hospital she had been

examined at home and roentgen examination of the petrous areas had been ordered. On the right side the continuity of the roof of the petrous pyramid from the superior semicircular canal to the internal auditory meatus was lost. Operation was performed as follows: After removal of the tegmen of the mastoid down to the superior semicircular canal, a tract of softened bone was found anterior to the canal and slightly above it. On withdrawal of the probing instrument (Yankauer eustachian curet) about 1 drachm (3 cc.) of thick whitish pus escaped into the cavity of the wound. The roof of this tract was removed until the abscess cavity was encountered. A ribbon of rubber dam was inserted as a drain, and the wound was closed in its uppermost part. Recovery was uneventful. The pain disappeared immediately after operation. The spinal fluid was normal at all times. Streptococcus haemolyticus was found in cultures and on a smear.

Summary

Date	Clinical Symptoms	Roentgen Findings	Operation and Findings	Comment
February	.....	.....	Mastoidectomy, both sides	
April 24	Symptoms of involvement of petrous pyramid			
May 8	.....	Erosion of roof of petrous pyramid between superior semicircular canal and internal auditory meatus	Tract of softened bone anterior to superior canal; pus evacuated	
June 3	.....	.....	.....	Discharged as recovered

Comment.—The condition in this case simulates that most frequently found in apical empyema, except that the terminal space which contained the empyema was not the apex but the space between the superior canal and the internal auditory meatus. Although the left mastoid wound was discharging profusely and the right wound was almost completely healed, the disease of the petrous pyramid developed on the right side. This demonstrates again that disease of the petrous pyramid follows no rule in regard to the presence or absence of discharge or its amount.

Case 3.—A Negro girl was seen by members of the otologic service on March 20, 1936. She had been a patient in the pediatric service since early in February, when she was admitted because of headache, fever, vomiting and drowsiness. At the time of her admission she presented exaggerated knee jerks and a bilateral Kernig reaction. The spinal fluid was withdrawn under slightly increased pressure and contained 8 cells per cubic millimeter. The urine contained a large amount of albumin and some pus cells. The temperature fluctuated between 101 and 104 F. On March 3 the left ear drum ruptured spontaneously, and the ear discharged profusely. The ears were dry on March 11, but the signs of meningeal irritation persisted. On March 15 the right ear began to discharge, the left remaining dry. Many pus cells were still present in the urine. On March 20 she was seen by the otologist, and a simple mastoidectomy was performed. Operation disclosed a well pneumatized mastoid; destruction was extensive. Dr. Coulter, bacteriologist, reported the presence of a mucus-forming type of hemolytic streptococcus in cultures. This indicated increased virulence. Two days after the mastoidectomy

facial palsy appeared, and two days after that the external rectus muscle of the same side became paralyzed. During the next three days the temperature did not go above 99 F. and the pulse rate was not higher than 96 per minute. Because of the involvement of the seventh and the sixth cranial nerve in rapid succession, infection of the petrous pyramid was suspected. Roentgen study revealed extensive destruction of the roof of the apical area. The plate taken in the base position gave positive evidence of involvement. At no time were there signs or symptoms pointing to disease of the petrous pyramid, except that of meningeal irritation, until involvement of the seventh and the sixth cranial nerve occurred. The meningeal irritation was present before there was evidence of otitic infection. Roentgen studies on successive days revealed a gradual increase in the size of the area of erosion of the roof of the apex. On April 4, after a preliminary lumbar puncture, the temporosphenoid lobe of the brain was elevated and a large apical cavity was evacuated. It was estimated that this cavity had contained about ½ ounce (15 cc.) of pus. On the seventeenth postoperative day the external rectus muscle began to resume its function and some movement of the facial muscles was noted. The ear was dry, and the whispered voice was readily heard. The sixth cranial nerve was functioning completely forty-six days after operation, while the seventh cranial nerve functioned completely on the sixty-first day.

Summary

Date	Clinical Symptoms	Roentgen Findings	Operation and Findings	Comment
Feb. 21	Illness began			
March 2	Headache, vomiting; fever, drowsiness, meningeal irritation	.....	.....	Admitted to pediatric service
March 3	Spontaneous discharge from left ear			
March 15	Discharge from right ear; left ear dry			
March 20	.....	.....	Mastoidectomy on right	
March 22	Facial palsy on right			
March 24	Paralysis of right external rectus muscle			
April 4	.....	Progressive destruction of roof of apex since March 24	Elevation of temporal lobe of brain; liberation of pus	
May 20	Sixth nerve regained function on forty-sixth day; seventh nerve on sixty-first day	.....	.....	Discharged; healed

Comment.—Could there have been an unrecognized otitis which was related to the early signs of meningeal irritation? This seems likely when one considers the unusual extent of the destruction of the roof of the apical area. While the patient was in the otologic service, her only symptom or sign of involvement of the petrous pyramid was the successive involvement of the seventh and the sixth cranial nerve within forty-eight hours of each other. The demonstration of apical

empyema by means of the roentgenograms in this case is the most striking we have seen (fig. 2).

Case 4.—A girl 8 years of age was admitted to the hospital on April 28, 1936. She complained principally of pain in the left eye. Her previous history was irrelevant, except that she had had measles three months before. Five weeks before admission a mastoidectomy had been performed on the left side. The

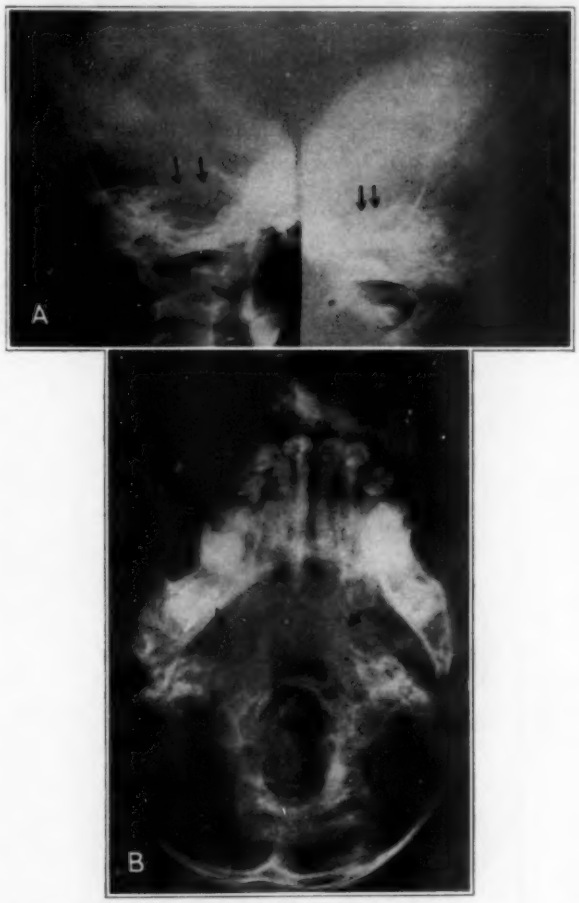

Fig. 2 (case 3).—*A*, a roentgenogram taken in the Stenver position before operation. Note the complete loss of detail in the area of the right petrous apex. The line of the roof of the apex is absent. This roentgen finding indicates empyema of the apical area. *B*, a roentgenogram taken in the base, or mentovertical, position. Note the loss of detail in the apical area.

same type of pain in the left eye which she had experienced before continued. The left ear had continued to discharge. The temperature was normal. She felt well except for the severe ocular pain. The ophthalmologist could find nothing wrong with the eye. Roentgen studies revealed that both petrous apexes were

pneumatic and that the left apex showed increased transparency, which extended beyond the roof. The mastoid wound was reopened; the semicircular canals were skeletonized, and tracts of softened bone were sought. None were found. During the next few days she was comfortable except for the ocular pain, which had persisted despite the operation. Three days after the operation and four days

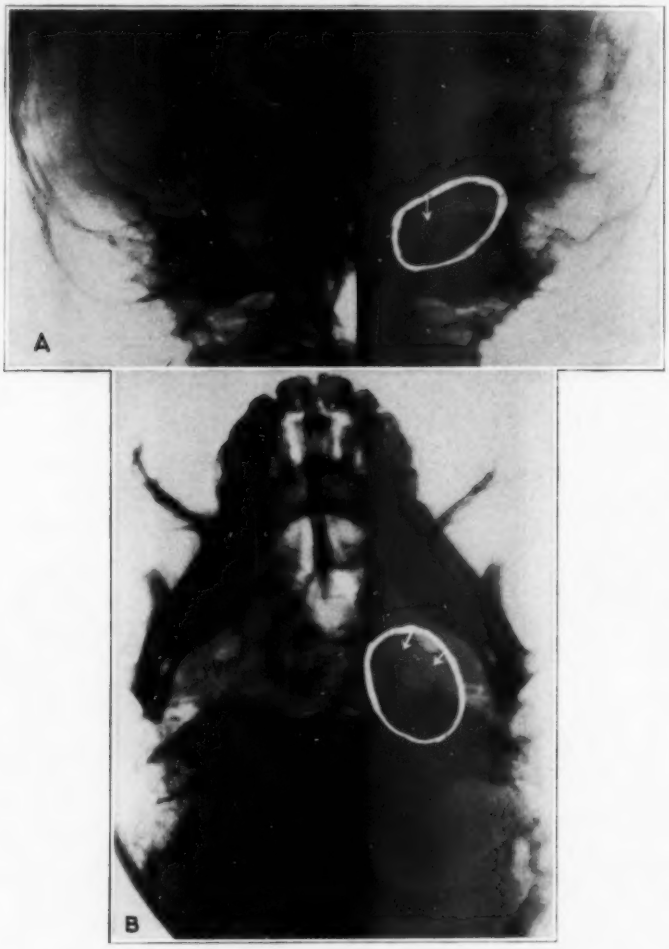

Fig. 3 (case 4).—*A*, roentgenogram taken in the Stenver position. Note the loss of detail in the apical area; also loss of part of the roof line of the apex, with extension of the apical shadow above this line. *B*, a roentgenogram taken in the base position. Note the loss of detail in the apical area.

after admission, although there were no signs pointing to meningeal irritation, examination of the spinal fluid revealed the presence of 200 cells per cubic millimeter. A blood transfusion was given, after which exploration of the petrous apex was carried out. The roof of the apex was eroded. Instead of pus,

however, we found the cavity filled with granulation tissue. After this operation the ocular pain disappeared, but the temperature became elevated, ranging between 100 and 104 F. There were no signs of meningeal irritation; yet on May 8 the spinal fluid contained 1,220 cells per cubic millimeter; 60 per cent of the cells were polymorphonuclears. Extensive exposure following the method suggested by Eagleton failed to reveal anything more than an apical cavity filled with granulation tissue. The next day the cells in the spinal fluid numbered 2,100 per cubic millimeter. Horizontal nystagmus was present, the greater component being toward the left; there were weakness of the left upper extremity and ptosis of the left upper eyelid. Hearing was present in the ear of the diseased side. The patient suddenly weakened and died on May 11. An autopsy could not be performed.

Summary

Date	Clinical Symptoms and Spinal Fluid	Roentgen Findings	Operation and Findings	Comment
March	.....	.....	Mastoidectomy	
April 28	Pain in left eye unrelieved by operation			
April 29	.....	Stenver position, increased transparency of apex extending beyond roof; base position, loss of bony structure		
May 2	Pain in left eye; temperature normal; no sign of meningeal irritation; 200 cells per cu. mm.	.....	Exploration of petrous pyramid; roof eroded, cavity filled with granuloma, no pus	
May 8	No sign of meningeal irritation; 1,220 cells	.....	Extensive exploration; cavity again filled with granulation tissue	
May 9	Horizontal nystagmus; ptosis of upper lid; weakness of left arm; 2,100 cells			
May 11	.....	.....	.....	Death probably due to cerebellar lesion

Comment.—Eagleton included a cariogranulomatous type of disease in his classification. What is the significance of this granuloma? Does it always imply a fatal outcome, and what can one do to combat it? It is probably caused by a specific subtype of Str. haemolyticus. Another patient had a granuloma with some pus and died of a temporal abscess. This patient probably had a cerebellar abscess.

Case 5.—This case is reported through the courtesy of Dr. Louis C. Menger, who cared for the patient throughout her illness. A girl 6 years of age was first seen on April 24, 1936. She had had measles three weeks before. Both ears became involved. A bilateral mastoidectomy became necessary on April 27. After the operation the temperature remained between 99 and 101 F. The left mastoid and the adjacent areas were well pneumatized, while those of the right side were less so. For two days prior to the operation she had complained of pain in the left eye and the frontal region. The left middle ear was dry, but the postauricular wound drained profusely. On the third day after operation the ocular pain became worse, so that she cried out at night and had little sleep. A roentgenogram of the petrous bone disclosed a loss of continuity of the line of the roof of the apex. On May 10 paralysis of the left facial nerve appeared. On

May 11 operation was performed to drain the apical area. A tract of softened bone extending into the apex was found anterior to the superior canal. Granulations were removed, and about a drachm (4 cc.) of greenish yellow pus was evacuated after probing. In addition, an extradural abscess was found over the anterior surface. This yielded approximately a drachm of pus. A drain was placed over the bone down to the apex. The ocular pain disappeared five days after operation; the fever disappeared at the same time.

Summary

Date	Clinical Symptoms	Roentgen Findings	Operation and Findings	Comment
April 27	Pain in left eye; frontal headache; middle ear dry; mastoid wound discharging	Empyema of apex	Mastoidectomy on both sides	
May 10	Facial paralysis			
May 11	.....	.....	Operation to drain apical area; fistula anterior to superior canal; epidural abscess on anterior surface of petrous pyramid	
May 29	Facial paralysis disappeared 11 days after operation	.....	.....	Discharged as well

Comment.—The roentgen findings in this case represent the most frequent type of empyema of the petrous apex. The facial nerve became involved in its course inward from the middle ear.

Case 6.—A girl 8 years of age experienced an earache on the left side on April 25, 1936. She was closely watched until June 5, when a mastoidectomy was performed on the right. At that time roentgenologic examination of the petrous area was inconclusive. She had been having left frontal headache since several days before the mastoidectomy. At the time of the operation the lateral sinus was found exposed but no lead into the apical area was found. During the seven days following the operation she experienced no headache. On the seventh day, however, she complained of severe frontal headache. A roentgenogram of the petrous pyramid in the Stenver position showed no involvement, but a roentgenogram in the base position revealed definite destruction of bone in the apical area. These roentgen findings indicated that the inferior aspect of the apical area was involved. Two days after the roentgen study localized pain developed to the right side of the upper part of the trachea. She also talked as if her palate were fixed or displaced. Examination with a mirror could not localize a nasopharyngeal abscess, but roentgen examination of the nasopharynx revealed a beginning abscess high up. When she was examined the next day, this abscess could not be palpated. On the same day a slight streak of thick, whitish pus coming from the roof of the nasopharynx was seen by means of the mirror. At the same time it was noticed that an unusually profuse discharge from the middle ear had developed. She spent her first comfortable night after this, and her temperature returned to normal. It should be mentioned that a granulomatous mass was present in the canal of the ear, extruding from the cavity of the middle ear. This granuloma persisted for two months after the child became comfortable and disappeared only when the discharge from the middle ear ceased (fig. 4).

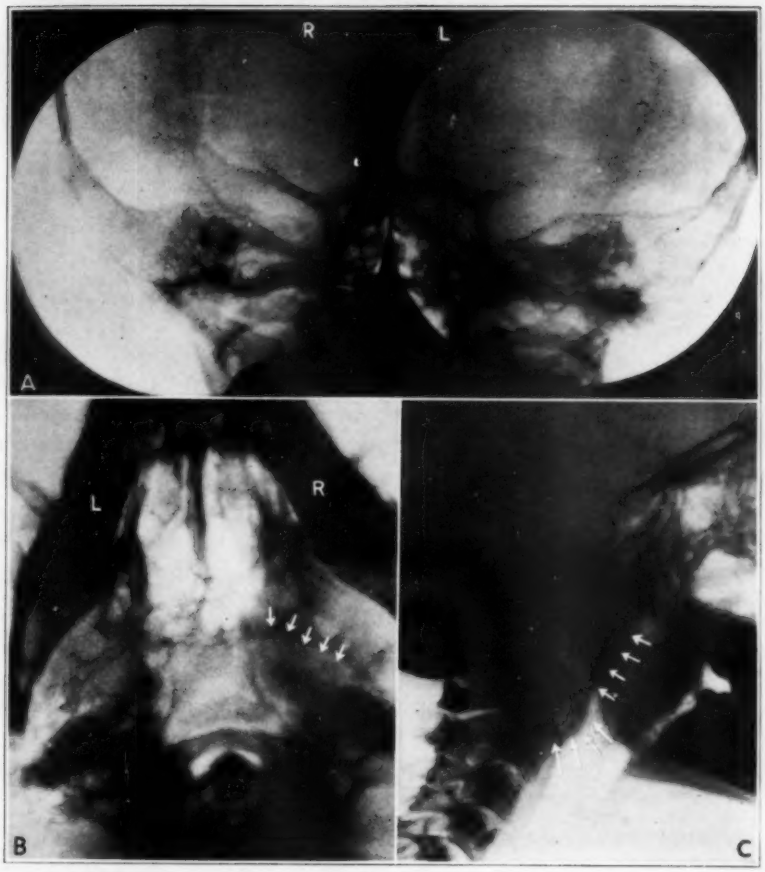

Fig. 4 (case 6).—*A*, a roentgenogram taken in the Stenver position. Note that there are no definite roentgen findings in the right petrous area. *B*, a roentgenogram taken in the base position. Note the loss of definition of apical structure on the right side. *C*, a roentgenogram showing an early stage of a high nasopharyngeal abscess coming from the inferior aspect of the petrous pyramid.

Fig. 5.—A roentgenogram showing slight haziness of the petrous pyramid as seen in cases of vascular spread of the disease.

Summary

Date	Clinical Symptoms	Roentgen Findings	Operation and Findings	Comment
June 5	.....	.....	Mastoidectomy	
June 12	Frontal headache	Stenver position, no involvement; base position, destruction of bone in apical area		
June 20	Fixation of soft palate	Early nasopharyngeal abscess		
June 21	Streak of pus in nasopharynx; profuse discharge from ear	.....	.....	Granuloma of middle ear persisted for two months

Comment.—This case afforded us the opportunity to make a diagnosis of disease of the inferior aspect by means of the roentgen findings. The film made in the Stenver position showed no involvement, while the film made in the base position showed destruction of bone. The discharge was much more profuse from the middle ear than from the nasopharynx. This would indicate that a softened tract of bone existed in the infralabyrinthine area, which finally yielded to the pressure of the trapped pus (empyema).

SUMMARY AND CONCLUSIONS

In most of the cases of surgically curable suppuration of the petrous pyramid the condition results in localized empyema of the entire apex or a part of it. Four different types of infection of the petrous pyramid in relation to the roentgen findings have been considered:

1. Empyema of the apex, which causes a break in the continuity of the roof of this cavity.

2. Localized infection (osteomyelitis) of the inferior aspect, with the formation of pus and usually a break into the nasopharynx, or empyema of an inferior cell in the apical area. For both these types the roentgenogram taken in the Stenver position shows no abnormality and that taken in the base position shows involvement.

3. A granuloma with or without pus, which is diagnosed by the extension of the shadow of the apex above the line of its roof.

4. A vascular spread through the petrous pyramid, which is indicated by essentially negative roentgen findings, with slight haziness of the entire pyramid.

Six cases are reported which have interesting and instructive features.

MEDIASTINITIS

A CLINICAL STUDY WITH PRACTICAL ANATOMIC CONSIDERATIONS OF THE NECK AND MEDIASTINUM

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The course of an acute suppurative process in the cervical region may cover a wide range of clinical manifestations and give rise to pathologic changes of a bizarre character. The capricious behavior and often bewildering influences of inflammatory disease in this part of the body have given rise to diligent research and clinical experimentation in this field. In this particular study laryngologists have advanced with striking rapidity. They have learned the great importance of early recognition of the many morbid changes produced by inflammation in the neck and the value of well directed surgical efforts in reducing the outcome to something less than an inevitable slow and painful death. To the sum and total of this knowledge have been added a clearer understanding of the mode of spread of infection to the mediastinum and rational methods for the treatment of an acute suppurative process within this part of the thoracic cage.

In this connection reference is made to acute mediastinal infection arising from an inflammatory process within the tissues of the mouth, pharynx or cervical region. For an understanding of the etiologic factors which favor the development of such a process, a study of the pathways along which infection may travel through the deep cervical tissues is imperative. To this end an attempt has been made to observe the complex arrangement of the cervical fascia in a study of serial sagittal and transverse sections of the neck and thorax, to which embryologic observations have been added in support of some of the opinions herein expressed. In order to gain a better perspective of these anatomic relations, gross dissections of the cervical region and thorax were made. These comprised a careful reflection of the planes of the body, commencing with skin and subcutaneous tissue and following in orderly sequence from without inward, layer by layer, until the dorsal

and cervical vertebrae were exposed. Thus, as one would read and turn the leaves of a book, from the first to the last page, the true story of an anatomic dissection is revealed and the relative importance of its component parts determined through a careful and orderly study of the adjacent structures of the body. In this way one may obtain, as by no other means, an explanation for the clinical behavior of many of the deep-seated suppurations of the neck and mediastinum.

THE FASCIA OF MUSCLES

In a general way one may classify the cervical fascia into two main groups of layers, each of which gives off innumerable connective tissue processes, which unite to form a structural support for the tissues within the neck. The first of these groups is a system of fascial planes which, starting above at the summit of the neck, descend with the cervical muscles to become attached to the upper edge of the thoracic cage. This group embraces the fascia of muscle, and from without inward it includes the superficial layer of deep cervical fascia, the fascia enveloping the omohyoid and the sternohyoid muscle and at a deeper level the fascia which follows the plane of the sternothyroid and thyrohyoid muscles (figs. 1 and 2).

This system of fascial layers forms spaces within the neck, described as the anterior, or previsceral, compartments. They do not communicate directly with any part of the mediastinum. Although they may appear to lie in relation to the retrosternal space, the attachment of their fascial walls to the upper margins of the thoracic cage forms their inferior limit and clearly separates them from any part of the thoracic cavity. Sagittal sections of a 3 month human embryo afford proof of this fact (fig. 2). In this section one observes that the innermost muscle layer of the neck is attached to the posterior surface of the sternum, forming the inferior boundary of the previsceral spaces within the muscles of the cervical region. It may be demonstrated further that iodized poppy-seed oil 40 per cent injected into this region fills the various spaces but finds a definite barrier below to its escape into the mediastinal cavity.

It would seem, then, that retrosternal infections are not to be considered in suppurative processes of the neck. This region, commonly referred to as the anterior mediastinum, is a small space which is separated from the cervical tissues by the thymic capsule. It is rarely affected by inflammatory processes, excepting those which extend from osteomyelitis of the sternum or occur as the result of penetrating wounds of the anterior wall of the chest. This fact is perhaps worthy of note when drainage of the mediastinum is to be considered.

The second group of cervical fasciae is of greater interest in this study, because it forms definite pathways along which infections may

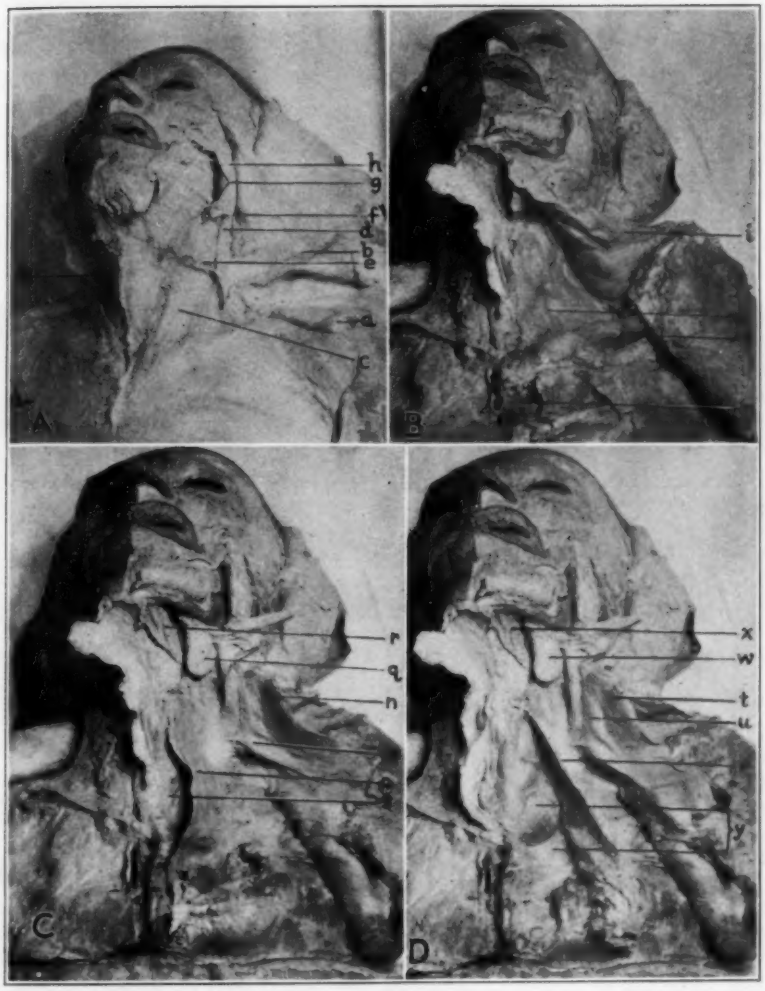

Fig. 1.—*A*, anatomic specimen showing reflection of the skin and subcutaneous tissue from the face, neck and thorax; *a* indicates the skin and subcutaneous tissue; *b*, the platysma muscle; *c*, the first plane of muscular fascia; *d*, the external jugular vein; *e*, the transverse cervical nerve; *f*, the great auricular nerve; *g*, branches of the facial nerve, and *h*, the parotid gland. *B*, the anatomic specimen showing the reflection of the first muscular fascial plane on the left side; *i* indicates the sternocleidomastoid muscle; *j*, the pectoralis major muscle; *k*, the second muscular fascial plane; *l*, the clavicle, and *m*, the sternum. *C*, the anatomic specimen showing the reflection of the second muscular fascial plane together with the clavicle and half of the sternum on the left side; *n* indicates the sternohyoid muscle with its investiture of fascia; *o*, the omohyoid muscle enclosed by fascia; *p*, the third fascial plane; *q*, the submaxillary gland enveloped by a capsule of thick, fibrous connective tissue; *r*, the digastric muscle, and *s*, the thyroid gland enclosed by the vasculovisceral fascia. *D*, anatomic specimen showing the reflection of the third muscular fascial plane; *t* indicates the sternohyoid muscle; *u*, the omohyoid muscle; *v*, the sternothyroid and the thyrohyoid muscle; *w*, the submaxillary gland; *x*, the digastric muscle, and *y*, the thyroid gland enclosed by the vasculovisceral fascia.

travel from the neck to the mediastinum. For practical purposes, one may divide this group into two main systems, each contributing to the formation of clearly defined fascial planes along which infection is prone to spread.

THE VASCULOVISCERAL FASCIA

The vasculovisceral system of fascia, as the name implies, envelops the viscera of the neck and mediastinum and likewise surrounds the

Fig. 2.—Low power photomicrograph of a sagittal section of a 3 month embryo, showing the innermost muscular fascial planes attached to the posterior surface of the proximal end of the sternum. *a* indicates the vasculovisceral system of fascia immediately behind the deep layer of the muscular fascial plane; *b*, the thyroid gland enclosed by the vasculovisceral fascia; *c*, the arch of the aorta; *d*, the thymus gland; *e*, the trachea; *f*, the posterior wall of the pharynx; *g*, the pleural cavity; *h*, the sternum; *i*, the tongue; *j*, the cricoid cartilage of the larynx; *k*, the hyoid bone, and *l*, the sternothyroid muscle plane, which is the innermost layer and because of its attachment to the under-surface of the sternum forms a definite barrier to the descent of infections which arise superficial to it.

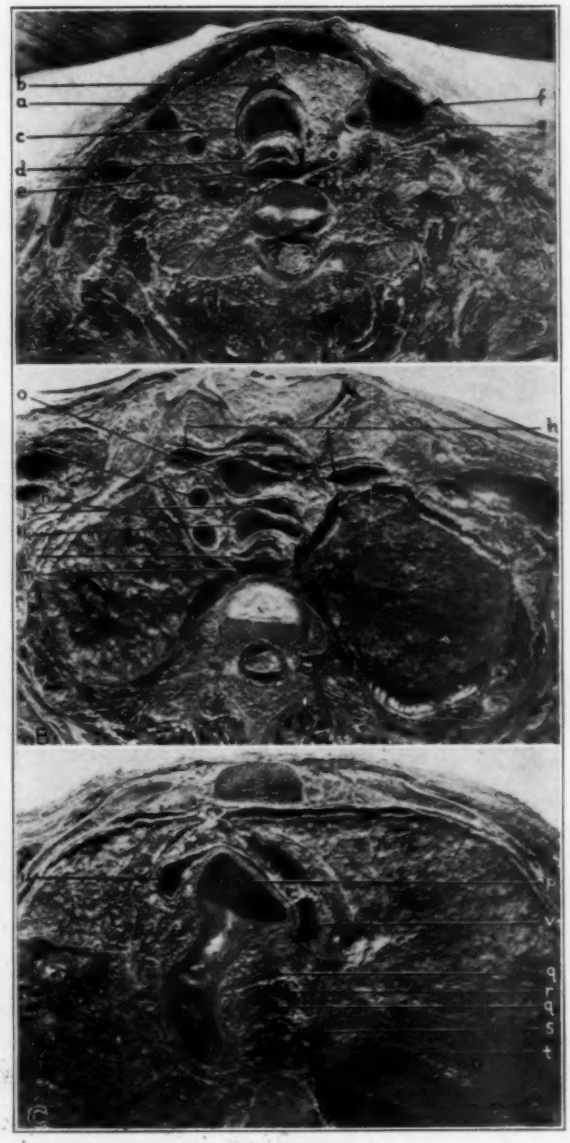

Fig. 3.—*A*, cross-section between the fifth and the sixth cervical vertebra, showing the anterior and posterior visceral spaces of the neck; *a* indicates the thyroid gland; *b*, the anterior visceral space; *c*, the trachea; *d*, the esophagus; *e*, the posterior, or retrovisceral, space; *f*, the internal jugular vein , and *g*, the carotid artery. *B*, cross-section of the cervical region at the level of the sternoclavicular joint, showing the vascular visceral system of fascia and the anterior and posterior mediastinal spaces; *h* indicates the left common carotid artery; *i*, the anterior mediastinal space; *j*, the trachea; *k*, the esophagus; *l*, the posterior mediastinal space; *m*, the left subclavian artery; *n*, the innominate artery, and *o*, the innominate veins. *C* is a cross-section of the anatomic specimen at the level of the arch of the aorta, showing the location of the anterior and posterior mediastinal spaces; *p* indicates the arch of the aorta; *q*, the anterior mediastinal space; *r*, the trachea; *s*, the esophagus; *t*, the posterior mediastinal space; *u*, the pericardial sac, and *v*, the superior vena cava.

carotid sheath, the aorta (its arch and descending portion) and its many branches. It forms a cylindric covering of the pharynx, larynx, trachea and thyroid gland and of the aorta and its branches which ascend into the neck. Within the thoracic cavity this fascial coat blends anteriorly with the pericardial sac, and behind surrounds the aorta and extends laterally with the intercostal arteries to become thin where it merges with the parietal pleura. At the level of the dome of the pleura this fascial layer is greatly strengthened to enclose the subclavian artery and

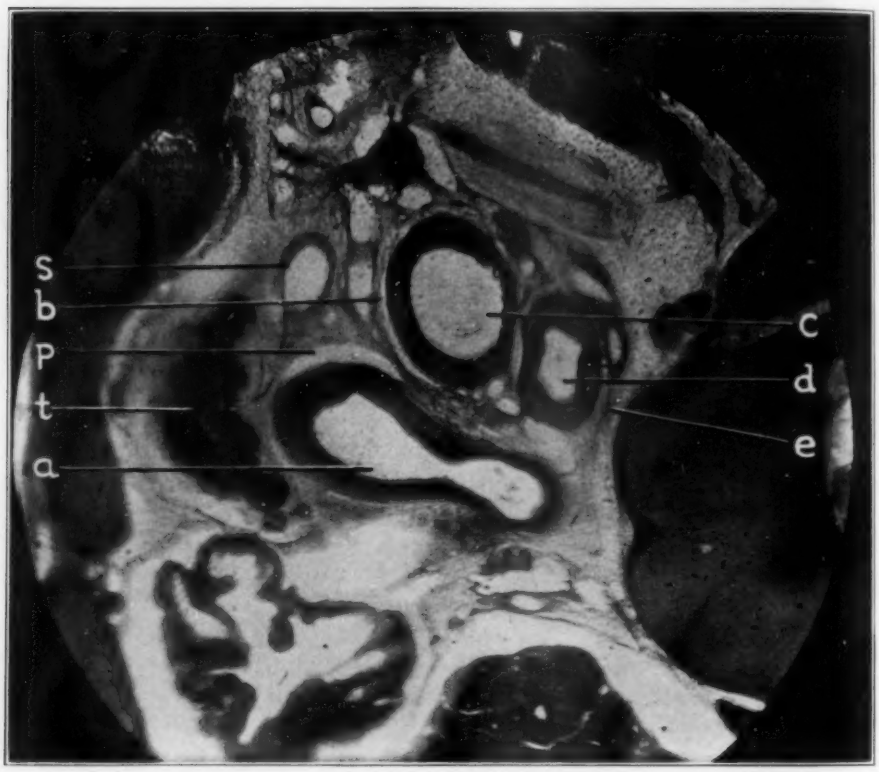

Fig. 4.—Low power photomicrograph of a 3 month embryo, showing the anatomic structures seen in figure 3 *B* and *C*. *a* indicates the arch of the aorta; *b*, the anterior mediastinal space; *c*, the trachea; *d*, the esophagus; *e*, the posterior mediastinal space; *p*, the pericardial sac; *s*, the superior vena cava, and *t*, the thymus gland enclosed by the superficial layer of the vasculovisceral fascia.

form the main suspensory ligament of the pleural dome (figs. 3 and 4).

For a clearer understanding of this fascial system, we traced its component parts from without inward in a sagittal section of a fresh specimen (fig. 5). Beginning at the lower border of the thyroid gland, a distinct layer of fascia descends in the neck to become attached to

the posterior surface of the sternum. It may be traced laterally as far as the external surface of the parietal pleura, where it forms the sheath of the internal mammary artery. Immediately beneath this fascial plane are uncovered the lymphatic drainage of the thyroid gland, the remains of the thymus gland and the inferior thyroid vein. Posterior to the thymus is observed another layer of fascia, which encloses the innominate veins and the superior vena cava, and extends from the

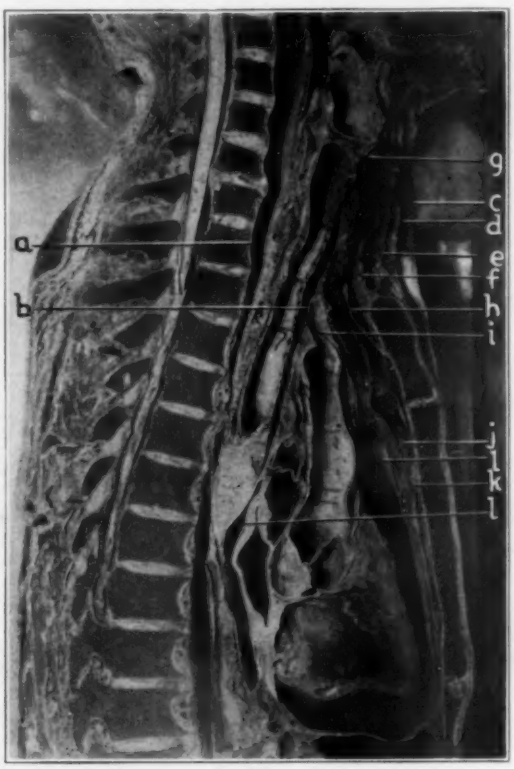

Fig. 5.—Sagittal section of an anatomic specimen demonstrating the different layers of fascia of the neck and mediastinum. This section corresponds with that shown in figure 2. The retropharyngeal space is continuous below with the posterior mediastinum. The anterior visceral compartment of the neck is exposed in this section, demonstrating its continuation with the anterior mediastinum below. The region between the sternum and the pericardium is called the substernal space. *a* indicates the posterior mediastinal space; *b*, the anterior mediastinal space; *c*, the skin with subcutaneous tissue and the platysma muscle; *d*, the sternocleidomastoid fascial plane; *e*, the sternohyoid and omohyoid fascial plane; *f*, the sternothyroid fascial plane; *g*, the vasculovisceral system of fascia; *h*, the vasculovisceral fascial system enclosing the thymus gland and the innominate veins (superficial layer); *i*, the vasculovisceral fascial system enclosing the ascending aorta and its branches (deep layer); *j*, the pleura; *k*, the retrosternal space, and *l*, the pericardial sac.

pretracheal fascia above to the mediastinal pleura below. Between this fascia of the superior vena cava system and the layer previously described, which extends from the lower edge of the thyroid gland downward and forward to the posterior surface of the manubrium, lies the thymic capsule, or thymic space, containing the inferior thyroid veins and the lymphatics of the thyroid gland.

As the dissection is carried deeper in the neck, the pretracheal fascia is next in order (fig. 6). Enclosing the larynx, trachea and thyroid

Fig. 6.—Anatomic specimen showing exposure of the first layer of the vasculovisceral system of fascia (pretracheal layer) after the muscular fascial planes have been reflected. *a* indicates the fascial plane of the sternocleidomastoid and the pectoralis major muscle; *b*, the fascial plane of the sternohyoid and the omohyoid muscle; *c*, the fascial plane of the thyrohyoid and the sternothyroid muscle; *d*, the thyrohyoid muscle; *e*, the sternothyroid muscle after the sternum and clavicle have been removed, showing the continuation of the first layer of the vasculovisceral system of fascia with the parietal pleura; *f*, the pretracheal fascia of the vasculovisceral system enclosing the thyroid gland; *g*, the thymus gland; *h*, the costal parietal pleura and the internal mammary artery; *i*, the intercostal muscle, and *j*, the right half of the sternum reflected upward.

gland, it descends into the mediastinum, surrounding the tracheobronchial lymphatic system, the arch of the aorta and the right branch of the pulmonary artery, to blend finally with the pericardial sac at the angle of reflexion of the parietal and visceral pericardium. Laterally in the neck the pretracheal fascia merges with the sheath of the common carotid artery. It continues posteriorly to form the retropharyngeal, or buccopharyngeal, fascia of the pharynx and the retro-esophageal fascia

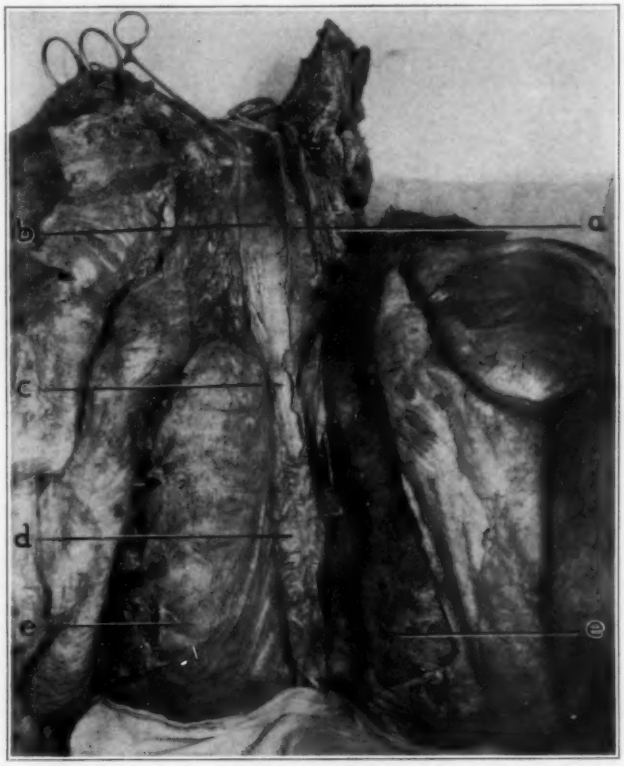

Fig. 7.—Posterior view of the anatomic specimen showing dissection of the retropharyngeal portion of the vasculovisceral system of fascia after the spinal column has been removed. *a* indicates the retropharyngeal portion of the vasculovisceral fascia; *b*, the pharynx; *c*, the esophagus; *d*, the descending aorta enclosed by the vasculovisceral fascia, and *e*, the right and the left lung covered by the parietal pleura.

of the esophagus (fig. 7), and where the left side of the trachea is crossed by the arch of the aorta, it continues downward to enclose the descending aorta.

Thus, there is formed within this fascial investiture the middle, or visceral, compartment of the neck. There is a wealth of experimental

evidence to prove that this space communicates directly with that part of the mediastinum which lies between the arch of the aorta in front and the trachea posteriorly (fig. 8). This region we term the anterior mediastinum, because it is the extreme anterior space which lies in direct communication with the fascial planes of the neck. The potential space immediately beneath the sternum and in front of the pericardium, usually referred to in anatomic texts as the anterior mediastinum, is, in our opinion, more correctly termed the retrosternal space. As pre-

Fig. 8.—The anatomic specimen showing the deep layer of the vasculovisceral system blending with the pericardial sac. A hemostat (*m*) is inserted in the anterior mediastinal space. *a* indicates the fascial plane of the sternocleidomastoid and the pectoralis major muscle; *c*, the fascial plane of the thyrohyoid and the sternothyroid muscle; *d*, the pretracheal fascia of the vasculovisceral system enclosing the thyroid gland; *f*, the thymus gland; *e*, the costal parietal pleura and the internal mammary artery; *h*, the deep layer of vasculovisceral fascia after a segment of the innominate artery was removed; *i*, the pericardial sac; *j*, the larynx; *k*, the trachea, and *l*, the pleuropericardial space.

viously demonstrated, this space does not communicate with the soft tissues of the neck and plays no part in the descent of suppurative processes below the lower boundaries of the cervical region.

The second division of the vasculovisceral fascia, the prevertebral system, lies in front of the bodies of the cervical and dorsal vertebrae from the basilar process of the occipital bone down to the lumbar region, where it blends with the external perimysium of the psoas muscle and the crura of the diaphragm. In the cervical region this fascia encloses the prevertebral muscles, and on each side of the median line it is reenforced by the perimysium of these muscles. In the region of the posterior mediastinum, below the level of the third or fourth dorsal vertebra, the prevertebral fascia loses this reenforcement and becomes exceedingly thin.

Fig. 9.—Transverse section of the neck through the fourth cervical vertebra, showing the size of the retrovisceral space (posterior compartment of the neck); *1* indicates the sternothyroid, the sternohyoid and the omohyoid muscle; *2*, the sternomastoid muscle; *3*, the thyroid gland; *4*, the trachea; *5*, the esophagus; *6*, the buccopharyngeal fascia; *7*, the prevertebral fascia; *8*, the retro-esophageal space; *9*, the internal jugular vein, and *10*, the common carotid artery.

The prevertebral fascia forms the posterior wall of the retrovisceral space, or posterior compartment of the neck (fig. 9). This space, which is perhaps the most important pathway between the upper cervical region and the mediastinum, is limited in front by the buccopharyngeal fascia, which is continued downward as the retro-esophageal fascia, and deep in the chest forms the interpleural ligament and the sheath of the descending aorta. By the injection of iodized oil the retrovisceral compartment can be visualized from the retropharyngeal region

above to the posterior mediastinum below. Moreover, it can be demonstrated that the iodized oil does not spread to adjacent parts of the neck but remains strictly confined to the boundaries of the retrovisceral space throughout its entire descent to the thoracic cavity.

The clinical significance of this pathway is obvious. Its intimate relation to the vertebrae, esophagus and lymph nodes within its upper extremity exposes it to infections from all sides. The occurrence of mediastinal suppuration secondary to retropharyngeal abscess has been common enough to command respect for the practical anatomic considerations of this important communication between the tissues of the cervical region and the posterior mediastinal space.

Fig. 10.—Transverse section of the upper part of the mediastinum at the sternoclavicular articulation, showing structures which divide the mediastinum into a larger (right) and a smaller (left) compartment. The esophagus as it enters the thoracic cavity lies in close relation to the pleura on the left side. The various structures are indicated by figures as follows: *1*, the space of burns; *2*, the sternothyroid, sternohyoid and omohyoid muscles; *3*, the sternal head of the sternomastoid muscle; *4*, the sternoclavicular articulation; *5*, the innominate artery; *6*, the trachea; *7*, the esophagus; *8* and *9*, the mediastinal lymph glands, and *10*, the pleura.

TREATMENT

In a previous publication, one of us (A. C. F.) discussed more precisely the surgical treatment of acute suppuration of the mediastinum. Some of the phases of this study are now reiterated in order that

a few links may be added to the chain of events which have transpired since the time of his first surgical efforts in this field.

Thoracic surgeons are more or less unanimous in the opinion that suppuration below the fourth dorsal vertebra calls for posterior drainage. Such processes, which occur low in the mediastinum, may arise from disease of the esophagus, caries of the thoracic vertebrae or extension

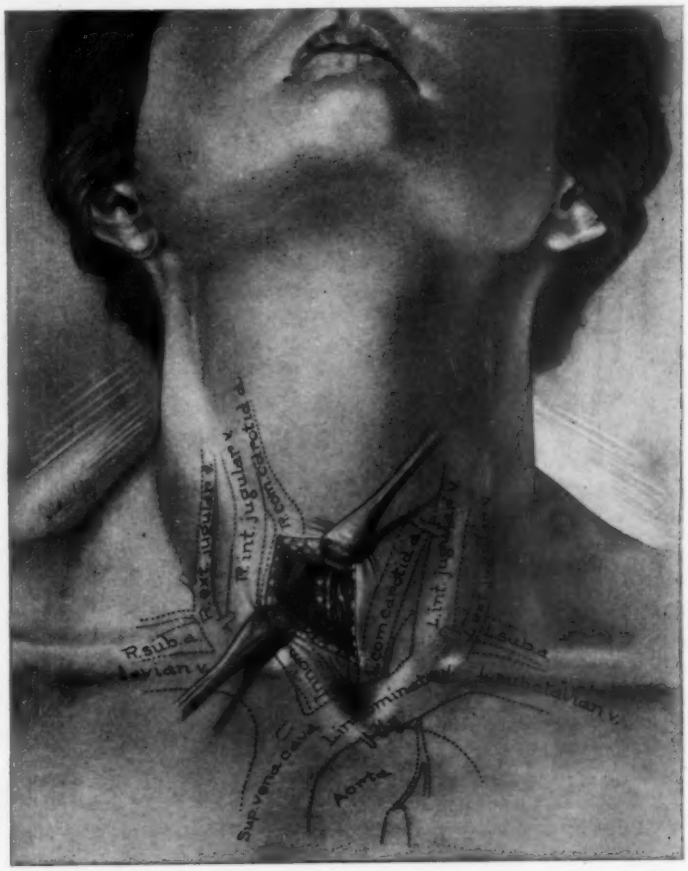

Fig. 11.—Diagram of the incision for cervical mediastinotomy showing the relation of the underlying structures.

from the abdominal cavity. These may be approached preferably and adequately drained by dorsal mediastinotomy, in which the thoracic cavity is opened posteriorly by resection of ribs or by the removal of one or more transverse processes with a portion of the attached rib.

Cervical mediastinotomy is a far more conservative measure and one which often serves admirably to drain infections in the upper portion

of the mediastinum. When pus enters the mediastinum from the neck, this procedure would seem the one of choice. To drain an abscess through the tissues which it has invaded is, we believe, a surgical axiom which in no other region of the body can be more advantageously applied.

Cervical mediastinotomy, moreover, has been successfully employed in traumatic perforation of the upper part of the esophagus. Through this technic, foreign bodies which have perforated the walls of the

Fig. 12.—Anatomic specimen similar to that shown in figure 8 after reflection of the larynx upward. In this specimen the hemostat (*a*) has been inserted into the posterior mediastinal space. *b* indicates the pretracheal fascia of the vasculovisceral system enclosing the thyroid gland; *d*, the thymus gland; *e*, the costal parietal pleura with the internal mammary artery; *h*, the deep layer of the vasculovisceral fascia after a segment of the innominate artery has been removed; *i*, the pericardial sac; *j*, the larynx; *k*, the trachea; *m*, the esophagus, and *n*, the innominate veins.

esophagus have been recovered. Esophageal perforations are sealed with packing to avoid fatal mediastinal emphysema, and drainage of subsequent mediastinal infection is adequately established. This is a

heroic measure, to be sure, but one which definitely possesses life-saving possibilities for the unfortunate victims of this grave accident.

The technic of cervical mediastinotomy is simple enough. One point of interest, however, is the selection of a site for the primary incision. This may be of little importance, although it occurs to us that the right side of the mediastinum is, for anatomic reasons, the logical approach. The three large arteries—innominate, left common carotid and left subclavian—esophagus, trachea and descending aorta divide the posterior part of the mediastinum into a right and a left compartment (fig. 10). The right compartment is the larger; it contains many more lymphatic glands and is therefore the site of predilection for inflammatory

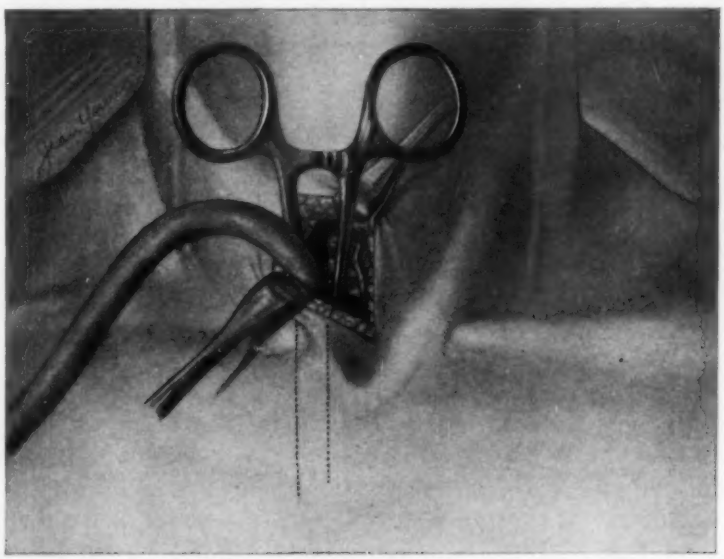

Fig. 13.—Introduction of a tube for drainage of a posterior mediastinal abscess.

processes in this region. A right-sided exposure of the posterior mediastinum is obviously the procedure of choice when there is reason to believe that infection has extended through the neck by the lymphatic route. Of considerable importance also is the fact that the esophagus on the left lies in close relation to the pleura as it enters the thoracic cavity, while on the right the pleura and the esophagus come in contact at a lower level behind the pericardium. Thus, in approaching the mediastinum on the right, there is less risk of injury to the pleura.

With the area under local anesthesia, an incision from 5 to 6 cm. long is made over the anterior margin of the sternocleidomastoid muscle down to the suprasternal notch (fig. 11). When the sternocleidomastoid,

sternohyoid and sternothyroid muscles have been exposed, these structures, together with the contents of the carotid sheath, are retracted laterally, exposing the trachea and, at a deeper level, the right side of the esophagus. It may be necessary to elevate the right lobe of the thyroid, in which event care must be taken not to injure the inferior thyroid artery, which enters the gland on its posterior surface close to its inferior pole. At this point one must choose to enter by blunt dissection either the anterior mediastinum, which lies between the trachea behind and the arch of the aorta in front, or the posterior mediastinum along the lateral wall of the esophagus. A guide to the procedure of choice might be found in a study of the etiologic factors producing the abscess. If suppuration has descended into the visceral space, it is presumptive evidence that the inflammatory process within the mediastinum will be found in its anterior part (fig. 8); if, on the other hand, the course of invasion is along the retrovisceral space, the posterior mediastinum becomes the logical site of predilection (fig. 12). A drainage tube is introduced, and suction is applied at frequent intervals (fig. 13). Some advantage may be derived from postural drainage by placing the patient in the Trendelenburg position.

EFFECT OF THE SHORT WAVE CURRENT ON THE TEMPERATURE OF THE PARANASAL SINUSES

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Because of the existing interest in the treatment of sinus infections by means of the short wave current, we made observations of the changes of temperature occurring in the paranasal sinuses as a result of the application of this current.

The technic we employed consisted in the use of a condenser electrode cut out in the shape of a butterfly so as to cover the region of the frontal sinuses, nose and maxillary antrums and another condenser electrode applied to the upper part of the back or else placed on a wooden chair, permitting the patient to sit on it. We also employed a solid oblong condenser electrode placed over the area of the forehead, nose, eyes and cheeks. These electrodes were separated from the skin by means of felt pads and towels. The machines which we used produced oscillations of 50,000,000, 20,000,000 and 18,750,000 cycles (wavelengths of 6, 15 and 16 meters, respectively). Within the range of these frequencies we did not note any decided variation in the heating effect of the different machines employed.

We used a special thermocouple to determine values for temperature. This thermocouple was long, thin and flexible, with an iron-constantan junction. It had been calibrated so that when attached to the registering instrument it showed accurate readings. The thermocouple was checked frequently against a mercury thermometer in a water bath.

Measurements of temperature were made with and without the use of local anesthesia. We observed that the use of a solution containing cocaine hydrochloride 10 per cent and epinephrine hydrochloride 1:1,000 had a decided influence on the changes of temperature. After the use of this mixture as a spray the values obtained became lower. The vasoconstrictor reaction following the use of cocaine and epinephrine frequently was not counteracted by the effect of the short wave current;

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so occasionally the temperature after the administration of the short wave current was lower than it had been prior to the application of the local anesthetic. We recognized that the use of local anesthesia distorted the values which would otherwise have existed. This may explain the results obtained by other investigators using local anesthesia, particularly when they employed large cannulas through which thermocouples were introduced.

Our first determinations were of the temperature in the nose. Table 1 shows the values for intranasal temperature in the region of the middle turbinate. It will be observed that a local elevation of temperature occurred in every instance when cocaine and epinephrine had not been applied. In those cases in which the cocaine-epinephrine solution had been applied, the temperatures rose above the values existing directly after the application of the solution, though in two of four

TABLE 1.—*Intranasal Temperatures: Region of Middle Turbinate*

Name	Date	Temperature Before Short Wave Treatment	Temperature After Application of 5% Solution of Cocaine and Epinephrine	Temperature After Short Wave Treatment	Body Temperature		Room Temperature
					Before Treatment	After Treatment	
I. W.	2/ 4	94.5	....	95.3	98.1	98.7	73.5
	2/ 7	93.0	....	95.0	98.2	98.3	74.0
	2/14	94.0	....	94.5	97.4	98.2	68.5
	2/19	90.0	....	95.0	97.2	98.0	74.0
	2/21	93.0	89.0	91.0	98.0	98.4	73.5
	2/24	89.0	87.0	90.0	98.0	98.6	72.0
	2/26	94.0	92.0	93.0	....	....	74.0
	3/12	93.0	90.2	94.5	....	....	....
	5/14	89.0	....	96.0	....	....	....

instances, the temperatures after the application of the short wave current were not as high as the initial readings. This occurred in spite of the fact that the body absorbed heating energy as evidenced by the slight rise in systemic temperature.

We determined the changes of temperature occurring in the antrums of a small group of patients (table 2). Intranasal antrotomy had been performed on these persons, making it relatively easy to bend the thermocouple and to insert it into the antrums. We observed that the elevations of temperature occurring after the application of the short wave current varied from 0.6 to 4 F. In these cases no topical applications were made. With one exception, the readings made after the application of the solution of cocaine and epinephrine were lower than the original readings, though they were either the same or higher than the values noted after the application of the local anesthetic. In all these instances the body temperature showed a slight rise.

We had the opportunity of making determinations of temperature in the sphenoid sinuses of forty-four patients who had undergone

spheno-ethmoidectomy. As a result of this operative procedure, the openings into the sphenoid sinuses were relatively large. This facilitated the introduction of the thin, long, specially devised thermocouple. To secure the true values for temperature as accurately as possible, we omitted the use of any topical applications. The temperatures in the sphenoid sinuses were noted before the short wave treatment was begun. The treatment was then administered to the point of comfortable tolerance and was permitted to endure for fifteen minutes. The current was then shut off; the electrode was removed from the face, and the thermocouple was quickly reinserted as nearly as possible into the same area, approximately the same amount of pressure being used when it was held against the posterior wall of the sphenoid sinus. Table 3 indicates the temperatures observed before and after the application of the current. It will be noted that the application of short wave

TABLE 2.—*Antrum Temperatures*

Name	Date	Temperature Before Short Wave Treatment	Temperature After Application of 5% Solution of Cocaine and Epinephrine	Temperature After Short Wave Treatment	Body Temperature		Room Temperature
					Before Treatment	After Treatment	
D. M.	4/16	94.0	92.2	98.0	99.8	100.4	76.0
	5/19	95.5	....	96.5	....	....	....
R. D. F.	2/ 7	92.0	....	92.6	97.4	98.2	....
	2/14	90.0	....	94.0	97.0	98.0	74.0
	2/19	91.0	....	94.5	97.0	97.8	68.5
	2/21	94.0	88.0	93.0	97.0	98.6	74.0
	2/24	95.0	94.0	94.0	97.0	98.0	73.5
	2/26	95.0	93.0	94.0	98.0	98.6	72.0
	3/10	96.0	94.0	94.0	97.0	98.2	72.0
	4/21	97.4	95.0	95.8	98.0	99.1	....

current was followed by a rise in temperature in nearly all instances (it fell from 0.5 to 1 F. in two determinations and remained the same in four others). The amount of elevation varied from 0.6 to 4.5 F. The average rise was 1.31 F. The greatest rise in temperature was observed in those cases in which the temperature before the treatment was relatively low. Conversely, the smallest rise occurred in those cases in which the initial temperature was relatively high. This was noted in the cases in which operation was more recent. We recognized that truer values would probably have been obtained if we had determined the temperatures in the sphenoid sinuses of patients who had not had any surgical intervention. As Andreen and Osborne[1] stated: "In cases in which an exenteration or a window resection had been done, the sinus merely becomes a part of the nasal cavity, and any heat

1. Andreen, M. A., and Osborne, S. L.: Measurements of the Temperature of the Maxillary Sinus After Treatment by Various Methods of Heating, Arch. Otolaryng. **24**:331-337 (Sept.) 1936.

which may be generated is dissipated much more rapidly than if the walls were intact. Furthermore, after surgical intervention there would naturally be some interference with the circulation of blood and lymph." It is possible also that the increased ventilation due to the presence of a large opening into the sphenoid sinuses may have an additional cooling effect. From our experience in determining the temperature-raising influence of the short wave current when applied to other parts of the body, we know that a fall in temperature occurs immediately after the cessation of the flow of current. Undoubtedly the period which elapsed between the interruption of the flow of current and the determination

TABLE 3.—*Temperatures of Patients with Widely Opened Sphenoid Sinuses Who Underwent Spheno-Ethmoidectomy (Yankauer Technic)*

Patient	Temperature in Sphenoid Sinus Before Short Wave Treatment	Temperature in Sphenoid Sinus After Short Wave Treatment	Patient	Temperature in Sphenoid Sinus Before Short Wave Treatment	Temperature in Sphenoid Sinus After Short Wave Treatment
1. M. K.	96.0	96.8	23. R. D. F.	99.0	99.0
2. M. S.	96.0	98.5	24. R. D. F.	97.2	98.7
3. A. A.	96.0	98.0	25. R. D. F.	97.5	99.5
4. J. S.	98.0	99.8	26. I. W.	93.5	96.0
5. M. K.	97.0	98.0	27. S. H.	97.5	98.0
6. H. L.	96.0	98.5	28. J. F.	97.0	97.5
7. J. N.	98.0	98.0	29. D. M.	99.0	98.5
8. J. D. Q.	98.5	99.0	30. B. K.	95.5	96.9
9. M. K.	96.0	97.2	31. M. R.	96.5	97.5
10. H. K.	96.0	97.0	32. F. B.	98.5	100.9
11. L. D.	95.0	96.0	33. B. K.	99.0	99.0
12. M. K.	97.5	98.0	34. Y. L.	96.0	96.5
13. D. F.	99.5	100.0	35. L. D.	97.0	98.4
14. C. F.	98.5	99.2	36. H. W.	95.0	98.0
15. M. K.	96.0	96.5	37. L. K.	98.0	99.6
16. J. F.	91.5	96.0	38. V. C.	92.0	94.0
17. T. D. P.	91.0	96.5	39. D. M.	100.0	101.0
18. A. W.	99.0	98.5	40. P. M.	100.0	100.0
19. P. S.	99.0	99.5	41. L. D.	100.0	100.0
20. D. M.	99.0	100.0	42. D. W.	97.0	99.0
21. R. D. F.	97.5	99.5	43. D. W.	93.0	96.0
22. R. D. F.	96.5	97.5	44. D. W.	93.0	94.5
Average				96.79	98.1

of the temperature was sufficiently long, even though the necessary maneuvers were performed with reasonable celerity, to be responsible for temperature readings lower than the true values.

The fact that in the majority of instances the use of the cocaine-epinephrine solution prevented the usual rise in temperature indicates that the major effect of the short wave current applied in the manner described is vasodilation. The final temperatures produced in the local areas treated were generally not higher than the systemic temperature. From our experiments in determining the temperature-elevating influence of the short wave current on tissue of the thigh in living man, we have learned that when the area of the electrode is large in relation to the cross-section of the mass heated it is possible to secure a substantial elevation of temperature. Thus, the temperature produced in

the muscles of the thigh may rise to 105 or 106 F. (when the rectal temperature is about 99 to 100 F.) when the so-called "cuff technic" is used. When the current is applied by means of the "lateral plate technic," which resembles the technics used in the making of our determinations on the paranasal sinuses, no such substantial rise occurs. It is possible that a variation of the "cuff technic" may produce higher degrees of temperature in the region of the head should such elevations be thought desirable.

CONCLUSION

It is possible to produce an elevation of temperature in the nose, in the antrums, and in the sphenoid sinuses by means of the short wave current. The preceding application of a solution of cocaine and epinephrine interferes with this rise.

STRUCTURAL ALTERATIONS IN THE PETROUS PORTION OF THE TEMPORAL BONE IN OSTEITIS DEFORMANS

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CHICAGO

INTRODUCTION

It has been known since the publication of Sir James Paget's [1] classic account that osteitis deformans "begins in middle age or later, is very slow in progress, may continue for many years without influence on the general health, and may give no other trouble than those which are due to the changes of shape, size, and direction of the diseased bones" and that "even when the skull is hugely thickened, and all its bones exceedingly altered in structure, the mind remains unaffected." The disease affects "most frequently the long bones of the lower extremities and the skull, and is usually symmetrical. The bones enlarge and soften, and those bearing weight yield and become unnaturally curved and misshapen. The spine, whether by yielding to the weight of the overgrown skull, or by change in its own structures, may sink and seem to shorten with greatly increased dorsal and lumbar curves; the pelvis may become wide; the necks of the femora may become nearly horizontal, but the limbs, however misshapen, remain strong and fit to support the trunk. In its earlier periods, and sometimes through all its course, the disease is attended with pains in the affected bones."

The bones of the skull are often involved, especially those which constitute its base; the petrous portion of the temporal bone is affected with the rest, and with its histopathologic picture in osteitis deformans we are particularly concerned. Relatively few accounts deal with osteodystrophic changes in the petrous pyramid, although, as emphasized by Nager and Meyer,[2] because of the "almost marrowless compactness"

From the Departments of Anatomy and Otolaryngology, Northwestern University Medical School; contribution no. 240 from the former; an investigation conducted under the auspices of the Central Bureau of Research of the American Otological Society.

1. Paget, James: On a Form of Chronic Inflammation of Bones (Osteitis Deformans), Med.-Chir. Tr. London **60**:37-64, 1877.

2. Nager, F. R., and Meyer, M.: Die Erkrankungen des Knockensystems und ihre Erscheinungen an der Innenohrkapsel des Menschen, Berlin, S. Karger, 1932.

and the partly embryonic structure of this part, special histologic forms might be expected to result from destructive disease. We therefore believe that the report of another case of osteitis deformans affecting the temporal bone may be of some interest to otologists.

Although detailed descriptions of the distinguishing features in this type of osteitis are to be found only in recent accounts, the chief histologic changes produced by the disease were clearly recognized in Paget's day; we find in Butlin's addendum to the original paper a description of the extensive resorption of osseous tissue and of the resultant formation of a thicker, more spongelike tissue. As pointed out by Schmorl,[3] the distinguishing histologic character of the bone—its mosaic architecture—is produced by the concurrent action of these two opposing processes. The same feature was emphasized by Knaggs,[4] who described the altered bone as "decorated with internal curvilinear markings" and, like Schmorl, regarded this peculiar pattern as histologically diagnostic of the disease. Later Freund,[5] Nager,[6] Jaffe [7] and others were struck by the completeness with which the regular lamellar arrangement is transformed into one suggestive of a mosaic consisting of pieces interlaid into an irregular pattern; the fragments, as noted by Jaffe, show little or no tendency to arrange themselves around vessels in the familiar haversian plan; they are set off from one another by heavily staining "cement lines," more prominent (on account of their width and deviousness) than the haversian lines of the adjacent intact tissue.

It is evident from this brief review that the histologic peculiarities of osteitis deformans are well known and their significance understood. The petrous portion of the temporal bone, however, possesses osseous tissue of an unusual type and houses the canals and ducts of the auditory and the equilibratory systems; this means that the progress of the disease in the temporal bone may be different from that in the other skeletal parts and that its spread may do more than weaken long bones and vertebrae, actually causing a loss of hearing or a disturbance of the sense of balance.

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3. Schmorl, G.: Zur Kenntnis der Ostitis fibrosa, Verhandl. d. deutsch. path. Gesellsch. **21**:71-86, 1926; Zur Kenntnis der Ostitis deformans Paget, ibid. **25**:205-214, 1930; Ueber ostitis deformans Paget, Virchows Arch. f. path. Anat. **283**:694-751, 1932.

4. Knaggs, R. L.: Osteitis Deformans (Paget's Disease) and Its Relation to Osteitis Fibrosa and Osteomalacia, Brit. J. Surg. **13**:206-237, 1925.

5. Freund, E.: Zur Frage der Ostitis deformans Paget, Virchows Arch. f. path. Anat. **274**:1-36, 1929.

6. Nager, F. R.: Die pathologische Anatomie der Labyrinthkapsel und ihre klinische Bedeutung, Ztschr. f. Hals-, Nasen- u. Ohrenh. **34**:72-125, 1933.

7. Jaffe, H. L.: Paget's Disease of Bone, Arch. Path. **15**:83-181 (Jan.) 1933.

MATERIAL AND METHODS

The temporal bones from a patient afflicted with osteitis deformans were supplied by Dr. Loyal Davis, professor of surgery. The bones were decalcified in a 3 per cent solution of nitric acid in a 10 per cent dilution of a solution of formaldehyde U. S. P. and embedded in pyroxylin. Both were sectioned in the horizontal plane at a thickness of 20 microns and stained with hematoxylin and eosin. All technical preparations were carried out by Miss Helen Banks, R.N., assistant in otology. For comparison, sections of normal and of osteoporotic bone were available in the otologic collection, and in general, were similarly prepared.

From the series of horizontal sections numerous tracings of typical microscopic fields were prepared with the Edinger projection apparatus; from these tracings the most illustrative representations of the histologic changes were selected for drawings.[8] These were supplemented by photomicrographs of diseased and of normal bone.[9] All our figures of osteitis deformans are taken from the temporal bone of one side, since that from the opposite side of the head is virtually its duplicate.

REPORT OF A CASE[10]

Clinical History.—F. B., a white man aged 59, was admitted to the hospital on November 16 and died on Nov. 18, 1934.

At the time of admission, the patient stated that for ten years he had been aware of a gradual change in his bodily condition and through the latter half of that period of a progressive decrease in stature, an increase in size of the head and an alteration in the shape of the thorax. He estimated that in ten years he had lost 8 inches (20 cm.) in height; the size of his hat had increased from 7⅜ to 7⅞, and in three years his weight had decreased 8 pounds (3.4 Kg.). He became progressively more stoop shouldered, and his neck became so shortened and fixed in the posture of flexion that he could no longer raise his head. Two years prior to his admission roentgenograms were taken of the skull and a diagnosis of osteitis deformans was made. A year before admission, while washing his face he experienced a severe sticking pain over the areas supplied by the ophthalmic and mandibular divisions of the trigeminal nerve on the right side, with recurrences of the pain on three ensuing days; two injections of alcohol were

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8. Figures 1 to 6 were prepared at a magnification of 20 diameters and reduced three-fourths in reproduction; figures 7 to 12 and 13 to 15, at 60 diameters, reduced three-fourths; figures 16, and 19 to 21 at 345 diameters and figures 17 and 18 at 600, all reduced one-half. Figures 1 to 6 include the osseous tissue only; the marrow and the membranous structures have been omitted to render the bony architecture more graphic; in figures 7 and 8, and 13 to 15 the margins of the tympanic mucous membrane and the vestibular periosteum have also been included; the margin of the dura mater is indicated in figures 9 to 12. In figures 16 to 21, in addition to bone, the osteoclasts and blood vessels are shown.

9. The photomicrographs in figures 22 to 28 were taken at a magnification of 70 diameters and reproduced without reduction.

10. The general autopsy was performed by Dr. Hamilton R. Fishback, assistant professor of pathology; the special autopsy on the head by Dr. Loyal Davis, professor of surgery, and Dr. David A. Cleveland, then fellow in surgery; from their detailed reports we have prepared the condensed account published here.

given at that time, but they furnished only temporary relief, and for almost a full year pains became more frequent and more severe; chewing, swallowing, talking, moving the tongue and washing the face were all capable of initiating the pain. Recently pain had not been confined to the ophthalmic and mandibular areas, and during the three weeks prior to his admission to the hospital it had been so severe and widely spread that he had eaten but small amounts of very soft foods.[11]

11. Paget wrote in similar vein on the history of his patient: "Till 1854, when he was forty-six years old, the patient had no sign of disease, either general or local." At that age "from no assigned cause, unless it were that he lived in a rather cold and damp place in the North of England, he began to be subject to aching pains in his thighs and legs . . . after about a year he noticed that his left shin was misshapen . . . I first saw this gentleman in 1856, when these things had been observed for about two years. Except that he was very grey and looked rather old for his age, he might have been considered as in perfect health. . . . His left tibia, especially in its lower half, was broad, and felt nodular and uneven, as if not only itself but its periosteum and the integuments over it were thickened." After seeing the patient three years later, Paget recorded: "He was in the same good general health, but the left tibia had become larger, and had a well-marked anterior curve. . . . The left femur also was now distinctly enlarged, and felt tuberous at the junction of its upper and middle thirds, and was arched forwards and outward, so that he could not bring the left knee into contact with the right. The left limb was about a quarter of an inch shorter than the right. The patient believed that the right side of his skull was enlarged, for his hats had become too tight; but the change was not clearly visible." The story of the disease in the next seventeen years, Sir James wrote, "may be briefly told and with few dates, for its progress was nearly uniform and very slow. The left femur and tibia became larger, heavier, and somewhat more curved. Very slowly those of the right limb followed the same course, till they gained very nearly the same size and shape. . . . The skull became gradually larger. . . . In 1844 he wore a shako measuring twenty-two and a half inches inside; in 1876 his hat measured twenty-seven and a quarter inches inside. . . .The whole of the cervical vertebrae and the upper dorsal formed a strong posterior not angular, curve; and an anterior curve, of similar shape, was formed by the lower dorsal and lumbar vertebrae. The length of the spine thus seemed lessened, and from a height of six feet one inch he sank to about five feet nine inches. At the same time the chest became contracted, narrow, flattened laterally, deep from before backwards. . . . His head was advanced and lowered, so that the neck was very short, and the chin when he held his head at ease, was more than an inch lower than the top of the sternum. The short narrow chest suddenly widened into a much shorter and broad abdomen, and the pelvis was wide and low. The arms appeared unnaturally long, and, though the shoulders were very high, the hands hung low down by the thighs and in front of them. . . . In December, 1872, sight was partially destroyed by retinal haemorrhage . . . and at nearly the same time he began to be somewhat deaf. In the summer of 1874 he had frequent cramps in the legs, and neuralgic pains, which were described as jumping over all the upper part of the body except the head. . . . After this time, January 1878, however, together with rapid increase of the growth upon the radius, there were gradual failure of strength and emaciation, and on the 24th of March, after two days of distress with pleural effusion on the right side, he died."

On entering the hospital the patient was nervous, irritable and emaciated; subject to headaches when coughing; stricken with trigeminal neuralgia which was described by him as unbearable; heart conscious usually, and subject to palpitation, but without tachycardia. Four years earlier he was confined to bed for two weeks with a mild decompensation; through the four years prior to examination he had edema of the ankles at the close of each day. He had been deaf in the left ear for twelve years and totally deaf in recent months (but without suppurative discharge or pain). His two children were both normal; a brother and a sister, both living, were in good health, but the skull of the mother (deceased) had been greatly enlarged and her posture stooped.

Physical Examination.—The patient's skull was large, with prominent frontal eminences; he was short necked, the occiput almost resting on the seventh cervical vertebra; he had marked kyphosis in the cervical and the thoracic region, with shortening of the vertebral column; the sternum and the anterior thoracic wall were prominent; the distance between the lowermost ribs and the iliac crest was very small; the femurs and the tibias were bowed sharply forward; the clavicles were large; the lower jaw was definitely prognathous, and the thorax was barrel shaped. The temporal and the radial arteries were prominent; the pulse was regular, the heart enlarged and the blood pressure 140 systolic and 90 diastolic.

General Autopsy.—The subject was an emaciated man 151 cm. in height. The head was enormously enlarged. The ribs, humerus, clavicles and femurs were markedly deformed, and the chest was barrel shaped. The eyeballs were prominent, the pupils dilated, the oral mucous membrane extremely anemic and the teeth wanting (dental plates in situ). There were no abnormalities other than fibrous adhesions which passed between the gallbladder and the greater omentum; the pleural and the pericardial cavity were free from adhesions and excessive fluid. The left ventricle of the heart was markedly hypertrophied; the wall of the right showed fatty infiltration. The endocardium of the chambers and valves was unchanged, except for considerable atheromatous thickening and calcification of the aortic cusps; the walls of the coronary arteries and of the aorta showed only moderate atheromatosis. The lungs, trachea and bronchi presented no evidence of abnormality. The thyroid gland, stomach, esophagus, spleen, liver, pancreas, intestines, adrenal glands, urinary bladder, testicles and pituitary gland were all of normal macroscopic appearance. Two small calculi were present in the pelvis of the left kidney; the lining of the renal pelvis was also somewhat roughened. The right kidney contained one large stone; its pelvis was roughened and granular. The tips of the pyramids of both kidneys contained collections of light yellow-red crystalline material. The prostate gland was considerably enlarged, weighing 50 Gm. The sternum, ribs, vertebrae and innominate bones displayed no changes discoverable by macroscopic examination. The femur and the calvarium, however, were greatly enlarged, and when cut were found to consist of a honeycombed mass of friable granular bone, enclosing about three-fourths marrow tissue and one-fourth hyperplastic tissue.[12]

12. In the case of the patient described by Sir James Paget, "the body was examined five days after death. . . . As it lay on a flat board its posture was remarkable, for the head was upraised to the level of the sternum, being supported by the rigid and arched spine, and the lower limbs, with the knees bent and stiff, rested on the heels and nates. . . . In no part, whether near or far from the diseased bones, was there an indication of any change of structure in skin, muscle,

Microscopic Examinations.—The lungs showed moderate emphysema. The myocardium was hypertrophied. The aorta showed a slight diffuse deposit of calcium throughout the wall. Slight fibrosis of the liver was noted. The kidneys showed slight arteriosclerosis. Passive hyperemia was present in the spleen. The prostate gland showed adenomatous hyperplasia. The pancreas, adrenal glands, thymus gland, testes and thyroid gland were normal.

Special Autopsy of the Head.—The calvarium was thick and spongy and everywhere adherent to the underlying dura mater; these adhesions were so strong that the dura could be removed only by cutting it from the brain. The floor of the cranial fossa was markedly irregular owing to bony overgrowth. The calvarium was at least 1 inch (2.5 cm.) thick in some areas (i. e., approximately seven times as thick as normal) and throughout was spongy and as crumbly as sandy mortar. Sections of the brain revealed normal ventricles and white and gray matter of usual extent. Small hemorrhages were present throughout the cortex, but there were no tumorous masses which might be associated with the pathologic condition of the bone.

OBSERVATIONS AND COMMENT

The pathologic changes in these specimens of temporal bone were more widespread and more destructive than those observed in the case reported earlier.[13] They extended over all the petrous portion from the tip to the epitympanic area and from the medial tympanic wall to the subdural table of bone, affecting to a degree even the walls of the cochlea, the vestibule and the semicircular canals.

The extent of the destruction wrought can be most clearly demonstrated by comparing the macroscopic architecture of the diseased bone with that of the normal bone. Thus, in the normal bone of a child 4½ years of age (fig. 1) the general appearance is one of denseness. The periotic capsule, within the petrous portion, contains few spaces large

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tendon, or fascia. . . . In the arteries of the lower limbs there was extensive atheromatous and calcareous degeneration . . . the bones of the vault of this skull were in every part increased to about four times the normal thickness. The whole outer surface of the skull cap was finely porous . . . the inner surface was comparatively smooth and appeared little changed, except by the enlargement of all channels and apertures for blood-vessels." The inner table was "in some parts porous or finely reticulate, in more looking compact and dense like limestone or white brick. . . . The rest of the thickness of this part of the skull, representing probably the altered diploë and outer table, was made up of bone in various degrees porous, cancellous, or cavernous, with spaces filled with soft reddish substance. . . . The bones of the face were not uncovered, but they showed, neither to sight nor touch, any appearance of disease; not a feature was unnatural. . . . The outer surface of the walls of the long bones was irregularly and finely nodular, as with external deposits or outgrowths of bone, deeply grooved with channels for the larger periosteal blood vessels, finely but visibly perforated in every part for transmission of the enlarged small vessels."

13. Wilson, J. G., and Anson, B. J.: Histologic Changes in the Temporal Bone in Osteitis Deformans (Paget's Disease), Arch. Otolaryng. **23**:57-77 (Jan.) 1936.

enough to appear in a drawing prepared at low magnification.[14] At the apex the trabeculae between the air spaces are wide and arranged in a fairly definite linear pattern; the wall of the carotid canal and the inner table of the skull are as robust as the trabeculae. The normal bone in older persons is likewise compact; in an adult 65 years of age (fig. 2) the bone of the capsule, of the internal lamina of the skull and of the trabeculae of the diploe are all substantial.[15] Even in those cases in which a process of senile osteoporosis has been slowly operative, the fundamental pattern is little changed (fig. 3).[16]

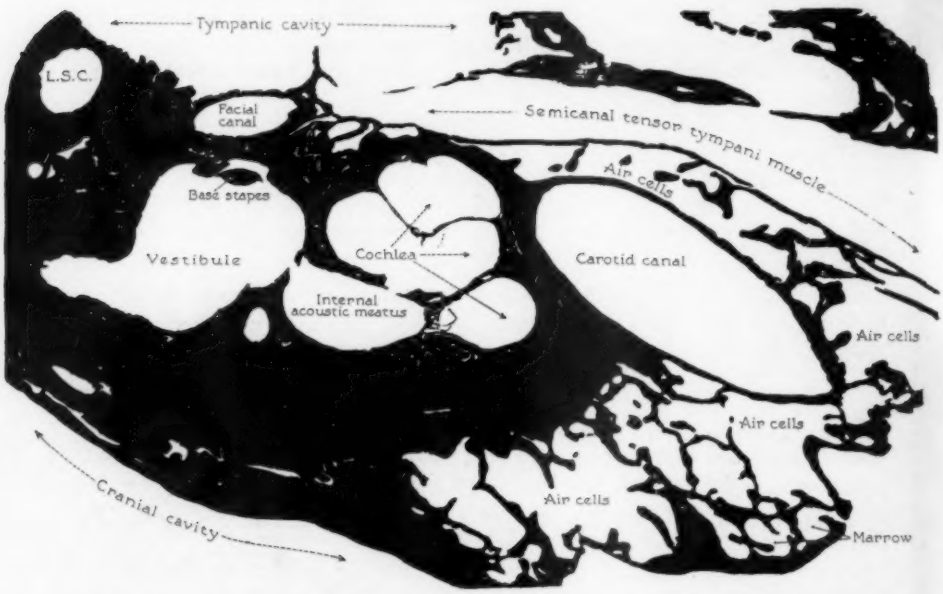


Fig. 1.—The normal architecture at low magnification of the temporal bone in the area of the otic capsule of a child 4½ years old. The section shows the relatively solid character of the bone (compare fig. 6). See footnote 8 for explanation of drawings. Magnification 5 diameters.

In osteitis deformans, however, the cancellous nature of the bony tissue is striking even at low magnification (fig. 6); the trabecular scheme is so completely modified as to bear little or no resemblance to that of

14. Such as do occur are either haversian or small marrow spaces surrounding the cochlea. Marrow spaces of this character regularly occur in the infant and the child, appearing in the very young as coalescent and setting off a cochlear shell from the surrounding bone; they diminish as age advances.

15. The section illustrated in figure 2 represents a level inferior to that in figure 1; the presence of marrow tissue gives it the appearance of porousness.

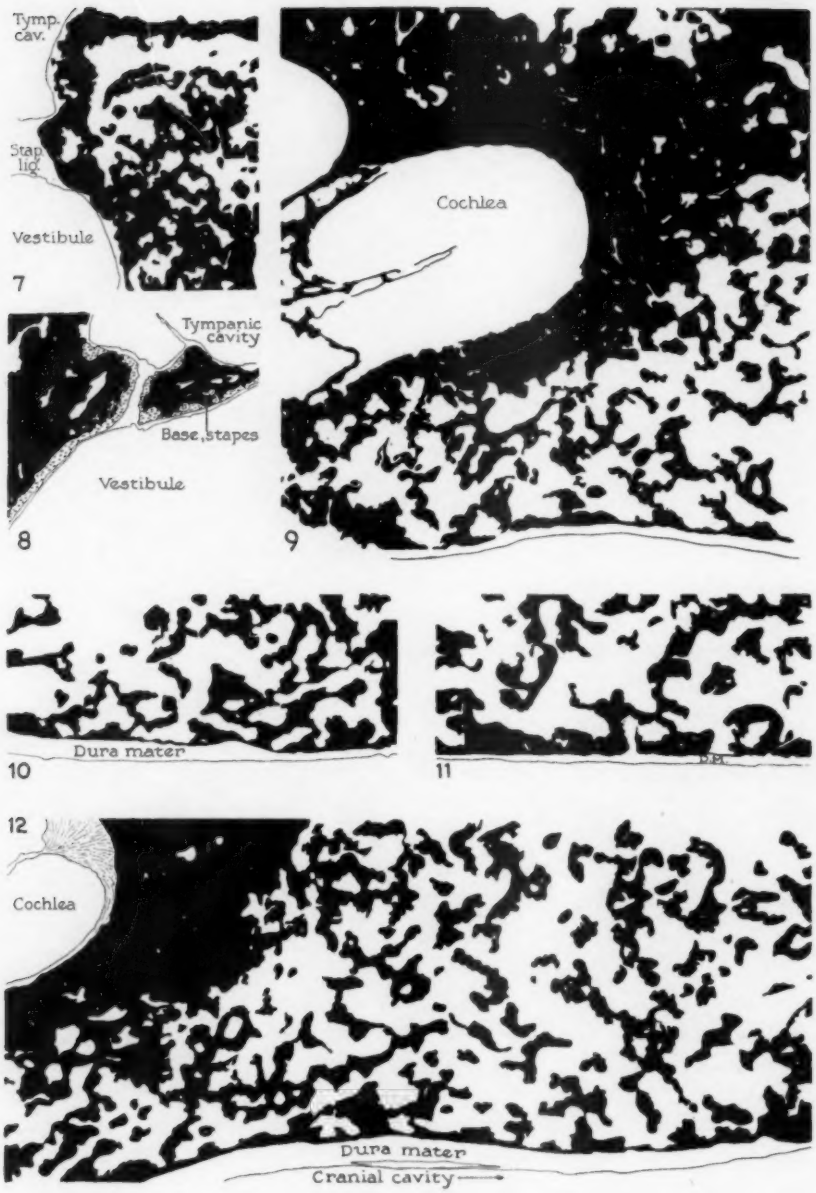
16. Even though through its loss of calcareous material the bone was rendered so fragile that it broke under pressure of the microtome knife.

Figs. 2 and 3.—Figure 2 shows the normal architecture of the temporal bone of a man 65 years of age. Magnification 5 diameters. Figure 3 shows the architecture of the temporal bone in osteoporosis in a man 68 years old. The section shows the somewhat spongelike nature of the tissue (see also fig. 26). Magnification 5 diameters. *P.S.C.* indicates the posterior semicircular canal.

normal bone (compare fig. 1), and those portions usually solid are spongelike. While in the case we reported earlier the capsular area remained relatively intact and some vestige of the original architecture persisted (Wilson and Anson,[13] figs. 4 and 41), in our present case the elongated trabeculae have been almost totally replaced by small irregular ones which present a multiplicity of forms (fig. 6). They are usually spiculiform rather than trabecular. No portion of the petrous pyramid is altogether spared: spongification is evident on the medial tympanic wall, to either side of the vestibular window and more strikingly on the anterior aspect of the latter in the region of the fissula ante fenestram; also, in the bone surrounding the cochlea, in that forming the wall of the internal acoustic meatus and in all neighboring bone even to the petrous apex (figs. 4 and 6). Only the bone on the posterior aspect of the vestibule (fig. 6), that immediately surrounding the superior and the posterior semicircular canal (figs. 4, 5 and 6) and the cochlea (figs. 6, 9 and 12) have escaped profound disorganization; the subdural bone of the internal lamina of the skull, both within the meatus (figs. 9 to 11) and facing the posterior cranial fossa (fig. 12), has been reduced to a layer of incredible thinness; the inner table has, in fact, been eroded to such an extent that at many points the dura is continuous with the fibrotic marrow. The area of the vestibular window is decidedly sponge-like in this specimen; it was unaltered in the one described earlier. On the anterior (fig. 7) and the posterior wall (fig. 8) the bone is rarefied; the condition is similar above and below the vestibular window (fig. 13) and near the adjacent fissula ante fenestram (fig. 22), but whereas this fenestral shell of bone exhibits changes in every respect like those observed in the remainder of the pyramid, the fenestral rim of cartilage, which constitutes the actual boundary of the window, is little altered, being eroded only on its anterior margin (fig. 15). The contained stapes is affected not at all, at its neck (fig. 13), along its crura (fig. 14) or within the base (fig. 15).

When normal long bone is examined microscopically, the tissue is found to be made up of concentrically arranged haversian lamellae and the interspersed interstitial lamellae; whether the bone is of the compact or of the cancellous type, the characteristic feature is this lamellar structure. In the diploic tissue of the cranial bones likewise the bars which cross the marrow spaces are lamellated evenly; the haversian canals are small smooth-walled spaces containing minute vessels and a slight stroma of connective tissue. In the bone of osteitis deformans, on the contrary, the canals have been enlarged and frequently communicate by wide orifices with the surrounding marrow spaces; the content of both is vascular connective tissue. The marrow contains little or none of the normal elements. The trabeculae are covered by an endosteal layer, not sharply separated from the tissue which fills the

Figs. 4 to 6.—The architecture of the petrous portion of the temporal bone in osteitis deformans in a man 59 years old. Magnification 5 diameters. Figure 4 shows a section through the ampulla of the superior semicircular canal and the cranial orifice of the internal acoustic meatus; figure 6, a section through the cochlea, vestibule and vestibular window (compare fig. 1). *S.S.C.* indicates the superior semicircular canal and *P.S.C.*, the posterior semicircular canal.



Figs. 7 to 12.—The altered architecture in osteitis deformans (continued); from the series illustrated in figures 4 to 6. Magnification 15 diameters. Figure 7 shows the changes at the anterior margin of the vestibular window (near the fissula ante fenestram); figure 8, at the posterior margin of the window; figure 9, at the basal turn of the cochlea; figures 10 and 11, along the anterior wall of the internal acoustic meatus; figure 12, on the inner table of the skull anterior to the cochlea. *Tymp. cav.* indicates the tympanic cavity; *Stap. lig.*, the stapedial ligament, and *D.M.*, the dura mater.

marrow spaces. This layer is highly active, containing an abundance of osteoblasts and osteoclasts.

Almost throughout the petrous pyramid this process of remodeling is an arresting feature. Destruction of bone is occurring simultaneously with new formation, the latter of the two processes appearing to surpass the other in intensity. The result is the production of soft bone, with the consistency of leather rather than of osseous tissue. The normal arrangement of trabeculae (figs. 1 and 2) no longer exists, and those which have replaced the original ones follow no regular scheme of radiation (figs. 4 to 6). The extent of the change is evident in almost any area selected, whether near the vestibular window (fig. 22, compare fig. 23), between the cochlea and the vestibule (fig. 24, compare fig. 25) or adjacent to the cranial cavity (fig. 28, compare fig. 27).

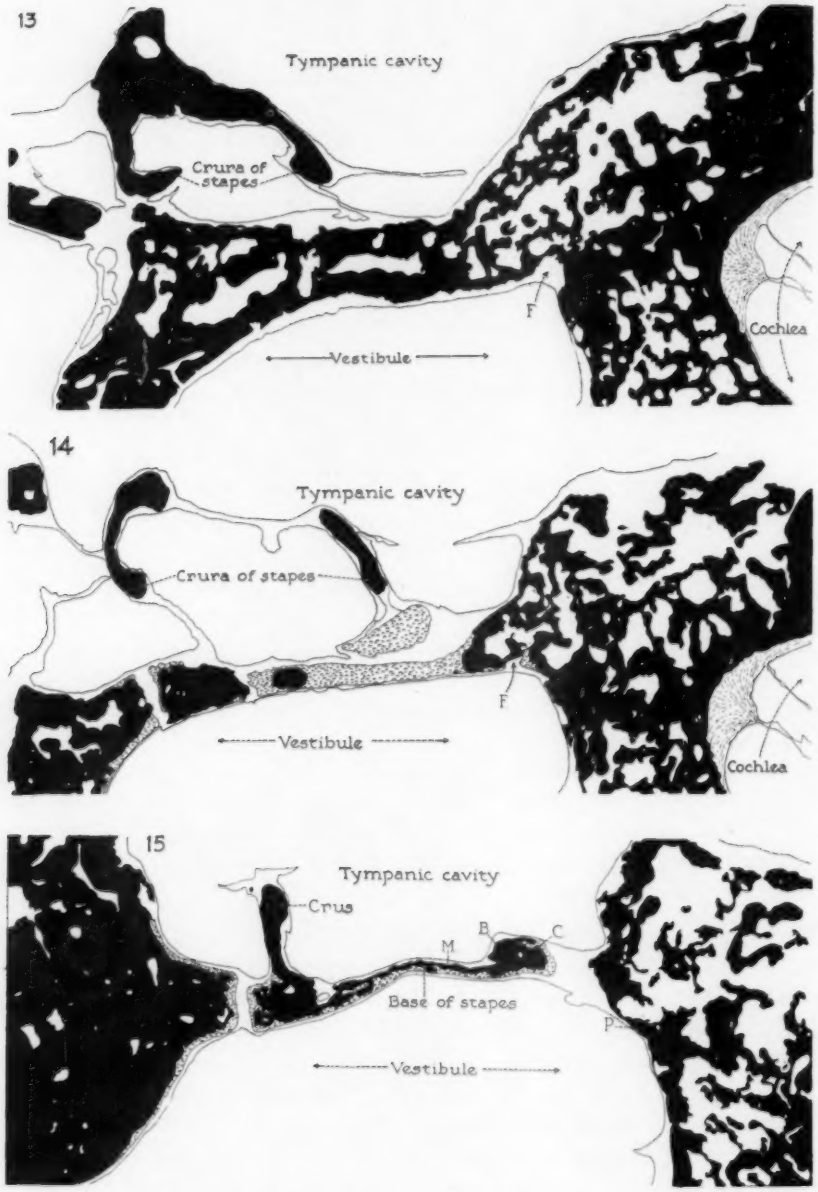
Throughout every section in the series the mechanism of rarefaction is evident on microscopic examination; the lamellae are eroded to produce irregular pieces of bone, which frequently resemble mere fragments; the irregularity of the reduced spicules is due to the presence on their surfaces of innumerable shallow pits, arranged in linear series along the border of a larger depression. The lesser excavations, which are the lacunae or foveolae of Howship, are usually occupied by large multinucelated osteoclasts; the constant presence of the osteoclasts along trabeculae which are undergoing resorption and their situation within the actual cavities leave no doubt as to their osteolytic function. All stages in the destruction of bone are encountered within the compass of any low power field, from those in which only the outer lamellations of a trabecula have undergone dissolution to those in which the pieces are either disjunct or remain connected by a little more than a strand (fig. 21).[17]

Osteoblasts abound in the fibrous marrow as well as in the immediate neighborhood of bone, so that commonly from fifteen to thirty may be seen in a single low power field,[18] the smallest number being five, the largest thirty-five. Many of the giant cells are closely applied to the bone, following even the minute scallopings, so as to leave a scarcely distinguishable space between the cell and the wall of the pit (figs. 16, 19 and 20), others conforming only in general contour. The pits not infrequently communicate with lacunar spaces occupied by bone cells, which have been opened by the action of the phagocytic osteoclasts.

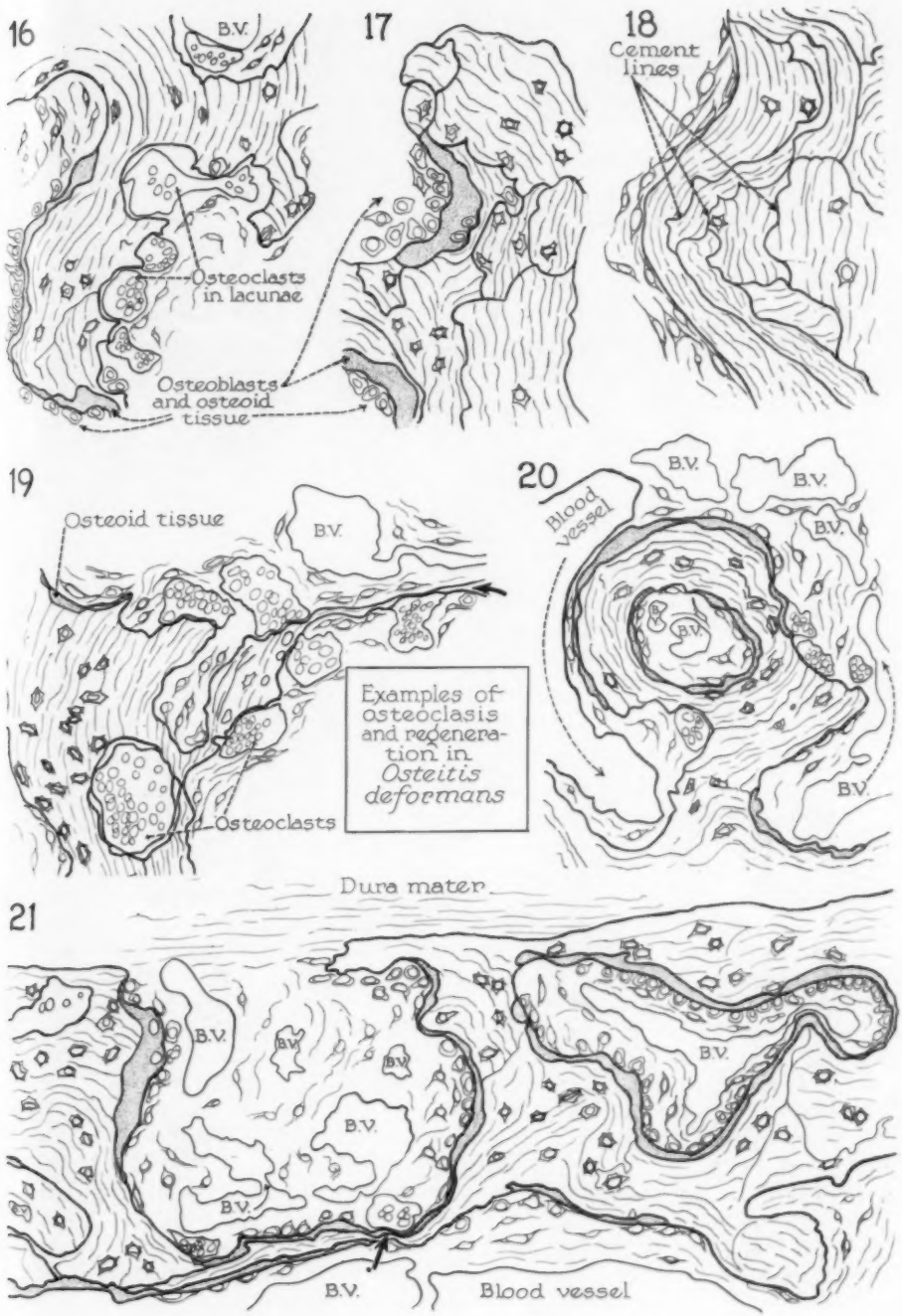
It would appear that in our specimen the destruction could be explained wholly on the basis of osteoclasis; osteoclasts occur in great numbers; they are rather constantly present where the trabeculae are

17. More extensively figured in our earlier paper [13] (figs. 5 to 34).

18. With 6 × ocular and 16 mm. objective.



Figs. 13 to 15.—The altered bone in osteitis deformans (continued); from the series illustrated in figures 4 to 12. The sections show the changes at the vestibular window, where the bone is eroded, the cartilage but slightly altered. Magnification 15 diameters. Figure 13 shows the bone external to the fenestral shell of cartilage; figure 14, the fenestral cartilage; figure 15, the base of the stapes and the vestibular window. *F* indicates the fissula ante fenestram, *B*, the bone, *C*, the cartilage, *M*, the mucous membrane and *P*, the periosteum.



Figs. 16 to 21.—The various forms of sculpturing and the relation of osteoclasts and osteoblasts to the eroded surface in osteitis deformans shown at high magnification from the series seen in figures 4 to 15. The magnification in figures 16, and 19 to 21 is 173 diameters and that in 17 and 18, 300 diameters. Figure 18 shows the cement lines of the mosaic bone, figure 17 the manner in which such an arrangement of lines is produced. Newly formed osteoid tissue is stippled; arrows mark the areas of deepest erosion. *B. V.* indicates a blood vessel.

furrowed by foveolae in which the giant cells lie nested, while in the intact tissue they are absent. It is recognized, however, that resorption cannot in all cases of pathologic involvement of bone be ascribed to the action of osteoclasts and that it may be brought about through the action of perforating blood vessels or through halisteresis.[19] In certain diseases of bone such noncellular agencies must be responsible, since although the tissue suffers decided alteration, no character of it suggests that osteoclasts have been at work and none are present in the sections.[20]

To discuss the feature of destruction in osteitis deformans without presenting some account of the associated one of regeneration would be to present a half-picture of the changes involved in the disease, since wherever destruction of the bone is evident new formation is equally prominent, the impression often being imparted that any exposed surface not being eroded by osteoclasts has received or is receiving a coating of newly formed osseous matrix.[21]

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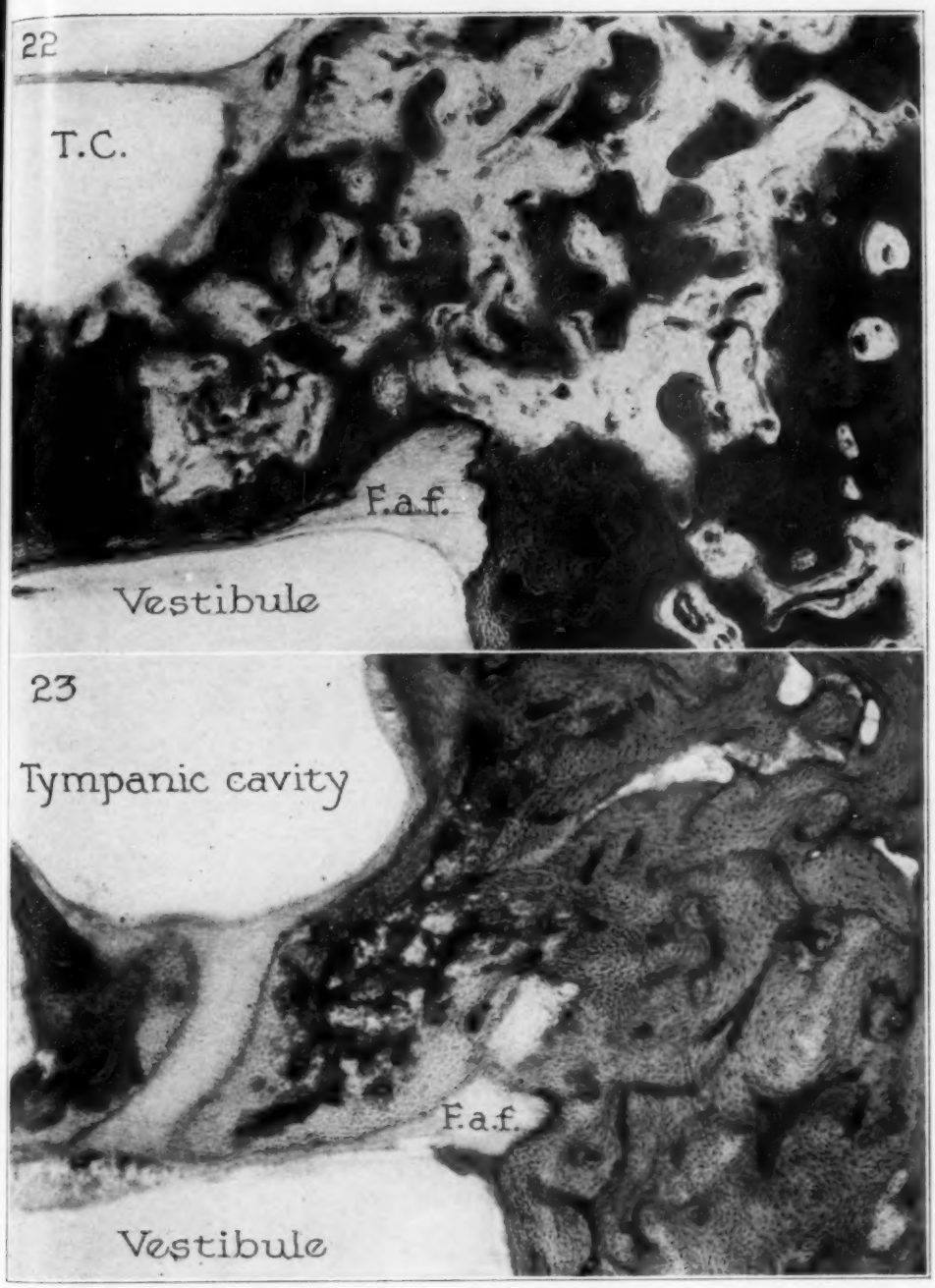
19. Processes which have been admirably described as operative in disease by Dawson and Struthers (Generalized Osteitis Fibrosa, Edinburgh M. J. **30**:421-564, 1923).

20. Osteoporosis is a disease of bone which belongs in this category, since disintegration with resultant fragility occurs in the absence of osteoclasts; just as there are present no cells of destruction, there are none of construction, and seemingly no new bone is added to the eroded surfaces. The whole bone suggests a devitalized fabric rather than one of which the structural plan is altered. The trabeculae exhibit a remarkably uniform picture; the portions of the trabeculae farthest removed from the surface are made up of streaked tissue, suggesting the fibrous ground structure of normal bone and seemingly brought out to view by an extraction of its calcareous content (fig. 26). The matrix is so profoundly altered that it appears almost cloudlike and is clearly seen only where it forms the walls of bone lacunae. It is not always set off sharply from the normal (solid, red-staining) bone; at some points the two types pass into each other by slow, almost imperceptible gradations, a condition which points to its not being new bone, but rather old bone somehow altered. This change is assumedly produced by a process of halisteresis, since osteoclasts are wanting. The rarefied tissue is almost always internal, i. e., in the deeper layers of the trabeculae—not external or peripheral, abutting on the marrow spaces. The marrow is of the normal fatty type. Fragmentation of the bone (fig. 3) is common (produced by pressure of the microtone knife).

21. It was fully realized by Butlin (in his addition to Paget's account) that the process involved in osteitis deformans is twofold; of the destructive phase he wrote: "The Haversian canals were enormously widened, many of them were confluent, and thus the appearance of a number of communicating medullary spaces was obtained, an appearance which was rendered still more striking by the presence in the canals of a large quantity of ill-developed tissue in addition to the blood vessels. The sides of the widened canals, instead of being smooth and even . . . are eaten out in a series of curves or concavities with the production of what are called Howship's lacunae." Of the agencies of regeneration: "The walls of some of the canals were lined by a single layer of osteoblasts, a condition precisely similar to that observed in the normal ossification of bone in membrane."

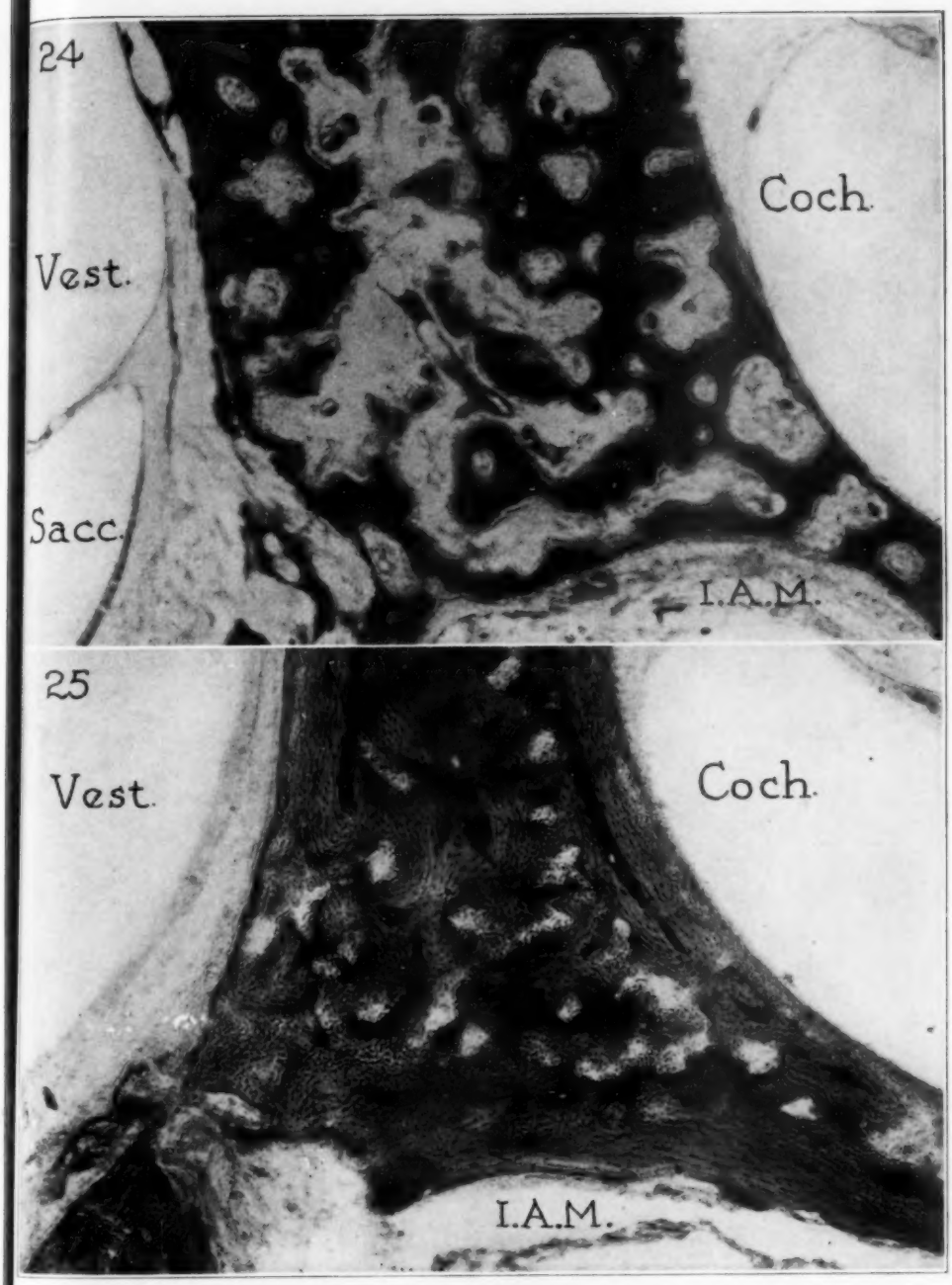


Figs 22 and 23.—The fissular area in osteitis deformans (fig. 22) and in a normal specimen (fig. 23). Photomicrographs; magnification 70 diameters. Figure 22 is a specimen from a man 59 years old; the section is slightly inferior to the level of the vestibular window and shows the eroded bone, the fibrous tissue of the marrow spaces and the resistant tissue of the fissular wall. From the series illustrated in preceding figures. Figure 23 is a section from a child 4½ years old, showing the normal bone and cartilage of the fissular wall and the cartilage of the fenestral rim (compare fig. 22). *F.a.f.* indicates the fissula ante fenestram and *T. C.*, the tympanic cavity.

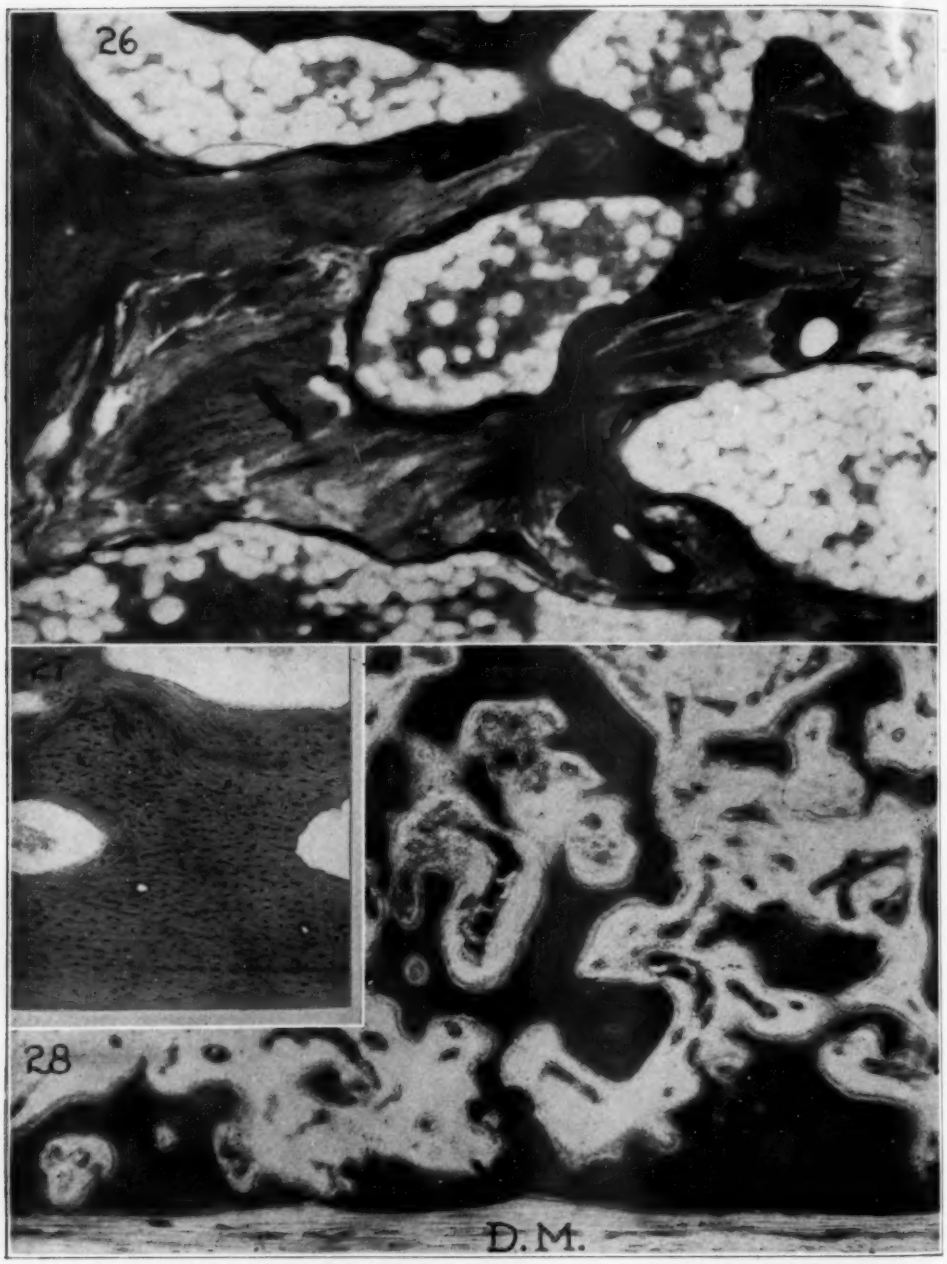
This appositional growth occurs through the agency of the osteoblasts.[22] These are of the typical polyhedral form, arranged along the margins of the trabeculae (figs. 16, 17, 21); the latter are covered by a smooth layer of osteoid material, which, like embryonic bone, is homogeneous and translucent; within it are some cells partly or wholly enclosed by the matrix (fig. 17). Smoothness is a quality of the superficies of the new pellicle, but the deep aspect is often scalloped, crenation being due to the lacunae of Howship, which, excavated earlier by osteoclasts, are now covered in by new matrix (figs. 17, 18). In the progress of these changes there is apparently no integration of the two opposing processes, such as obtains regularly in the development of normal long or tabular bones. Deposition of matrix proceeds without relation to previously existing deposits, with the result that the lamellae of the old and of the new tissue are not in the normal parallel relationship in the thinned trabeculae of the cancellous part, nor are they, in the compact bone of the capsule, arranged as the familiar concentric and interstitial lamellae; actually, since the new bone is built on the persistent spicules of the old, the patterns in lamination rarely correspond. It is through the operation of this mechanism that the intricate maze of separate lamellar lines is produced. The altered spicules contain only the undestroyed haversian systems of the original bone, so that the new pattern is not haversian; stratification is no longer smooth and regular but is everywhere interrupted to form separate segments, which, arranged contiguously, constitute the typical pattern termed mosaic. The adjacent pieces, representing successive local waves of osteogenesis and osteolysis, are set off from one another by cement lines.[23] The latter appear with great clearness (fig. 18), and along their course minute fractures are present in our sections; this weakness in individual spicules doubtless produces that softness of the whole bone which is characteristic of Paget's disease. The original marrow

22. We cannot agree with Leriche and Policard (The Normal and Pathological Physiology of Bone, St. Louis, C. V. Mosby & Company, 1928) in their opinion that there is no coincidence between osteogenesis and osteoblasts. Reaffirming a position already expressed[13] (footnote 10, p. 69), we believe that the osteoblasts are the agents of osteogenesis, a belief that rests on facts similar to those on which is based the accepted opinion that osteoclasts have the opposite function; they are invariably present in great numbers where the light-staining new osteoid matrix is being added to the formerly eroded spicules; they are immediately in contact with the new tissue, their flat surfaces conforming to the smooth margins on which they rest; where in this active tissue the spicules have not received an osteoid covering, osteoclasts are absent.

23. A term employed by Jaffe, which, while being descriptive, and from the functional standpoint wholly applicable, is not altogether fortunate, since the same name has long been applied to the dark-staining thin layer of matrix in normal bone, which sharply limits each lamellar system from its neighbor.



Figs. 24 and 25.—Pathologic (fig. 24) and normal bone (fig. 25) from the area bounded by the internal acoustic meatus, cochlea and vestibule. Photomicrographs; magnification, 70 diameters. Figure 24 is a section from a man 59 years old who had Paget's disease, showing the results of osteoclasis; the widened spaces contain a vascular connective tissue and numerous osteoclasts. Figure 25 shows a section from a child 4½ years old. The bone contains some areas of modified cartilage and a few small haversian spaces. *Coch.* indicates the cochlea; *I. A. M.*, the internal acoustic meatus; *Sacc.*, the saccule and *Vest.*, the vestibule.



Figs. 26 to 28.—Pathologic (figs. 26 and 28) and normal bone (fig. 27). Photomicrographs; magnification, 70 diameters. Figure 26 shows a section from a man 68 years old who had osteoporosis (compare fig. 3). Unlike the condition found in osteitis deformans, no osteoclasis occurs; the calcium content has been greatly reduced. Figure 27 shows a section from the inner table of the skull near the internal acoustic meatus of a child 4½ years old. Figure 28 shows a section from a similar area from a man of 59 who had osteitis deformans. The marrow is separated from the dura mater only by a thin lamina of bone (compare figs. 9 to 12).

is entirely replaced by fibrous tissue in which blood vessels are numerous (figs. 22, 24 and 28), suggestive of the changes observed regularly in von Recklinghausen's disease; neither the reticulum nor the cellular content of normal marrow is present; the fibrous tissue blends, along the spicules, with the osteogenic internal periosteum, in which, as described, osteoblasts abound.

In our earlier article it was stated that in the case therein reported one portion of the petrous pyramid—the periotic capsule—possesses "more than the usual power of resistance to the destructive agencies" at work in osteitis deformans and in degenerative disease of the bone characteristic of old age. Our present case strengthens this opinion, since the bone immediately surrounding the semicircular canals (figs. 4 and 5) and the vestibule and cochlea (fig. 6) is less affected by osteoclasis than that of the more peripheral regions; least affected are the fenestral shell of cartilage (fig. 14) and the cartilage on the vestibular aspect of the base of the stapes (fig. 15). On the contrary, the bony shell external to the cartilage of the vestibular window has been rendered excessively spongy (fig. 13). In the present case only those parts of the osseous labyrinth which lie at the base of the cochlea and between the latter and the vestibule have been deeply eroded. This special bone contains the cartilage islands, or interglobular spaces, fully described by Bast.[24] And, while we believe that in other cases the intrachondrial bone makes for a slower progress of a chronic degenerative change of the bone, such as was occurring in this case, the cartilage bone in the present instance cannot be regarded as the factor operating to protect the capsule, since it is small in amount and, where present, not coextensive with the areas spared. Possibly the lower vascularity of that part, with the fewer avenues for the entrance of phagocytic cells, may contribute to the stability of the perilabyrinthine bone.

SUMMARY

1. The petrous portion of the temporal bone in osteitis deformans (Paget's disease) is converted into highly spongified tissue, a condition early recognized as characteristic of long bones affected by this disease.

2. So profound is the histologic alteration that its effects are readily recognizable even in examination with the naked eye of sections prepared from the diseased bone.

3. Resorption by osteoclasts lodged in Howship's lacunae accounts for the osteolysis; it is through the operation of this histologic mecha-

24. Bast, T. H.: Ossification of the Otic Capsule in Human Fetuses, Contrib. Embryol. (no. 121) **21**:53-82, 1930.

nism that trabeculae, once broad, are reduced to thin spicules, which are mere sculptured fragments.

4. Osteolysis is everywhere accompanied by osteogenesis, the latter process being so widespread as to affect almost all surfaces not then being eroded, and so haphazard and uncontrolled as to fill and obliterate lacunae previously deepened by osteoclasts.

5. The deposition of new matrix on the foveate margins of the spicules results in the formation of bone in which the normal lamellar plan is wanting; in this "complicated cycle of bone resorption and apposition" to which the new as well as the old bone is being repeatedly subjected each fresh encroachment leaves a resorption line "part or all of which remains as a cement line when the new bone is deposited;" these lines "with the intervening fragments of bone create the mosaic architecture" (Jaffe), a feature so characteristic of Paget's disease as to be histologically diagnostic. Concurrently, the marrow is changed to a fibrous tissue, fat free and vascular.

6. Although in the diploic portion of the temporal bone the manifestations of the disease are in every way similar to those which obtain in any long bone, in the compact periotic capsule some factor seemingly operates to lessen its destructive effects or to delay its invasion; the presence of intrachondrial bone and the lower vascularity of the area are suggested as possible explanations of this resistance.

7. Alteration is more marked in the area situated anterior to the vestibular window (i. e., between the stapes and the cochlea) than in the region posterior thereto.

Clinical Notes

AN UNUSUAL TUMOR INVOLVING THE MAXILLARY ANTRUM

BEN L. BRYANT, M.D., LOS ANGELES

A certain amount of confusion has always existed in positively identifying and diagnosing the various tumors involving the antrum of Highmore, particularly those of dental origin, and although several attempts have been made by competent authors to classify these tumors properly, a part at least of the confusion persists. This is due, no doubt, to the fact that occasionally there is encountered a tumor of such location and origin which because of certain of its features does not permit ready and definite cataloging according to established concepts.

It is generally accepted that the odontoma, or dentigerous cyst, is a teratoma arising from a dental follicle occurring as a misplaced anlage, and such a tumor is characterized by the presence of a normal or an embryonic tooth within its wall and hence is comparatively easy of classification.[1]

The adamantinoma originating from the paradental epithelial débris is, according to Ewing,[1a] a slow-growing tumor which distends the tissues until it is surrounded by a thin, parchment-like bony capsule which crepitates on pressure. It occurs chiefly in adults with a history of previous extraction of a carious tooth and presents as a solid or cystic tumor. If cystic, it may be unilocular or multilocular, and in the cyst wall cellular or fibrous connective tissue is found. There may also be calcific particles in the fluid within the cyst. Ewing pointed out that the lower jaw is the chief seat of the cystic tumor, whereas in the upper jaw in most instances an adamantinoma is solid and apt to be malignant. He emphasized the slow growth of these tumors and the possibility of intermediate and transitional forms.

According to Becker,[2] the radicular cyst, which is apparently an outgrowth from an apical granuloma secondary to hemorrhage into the pericemental membrane, is also a slow-growing tumor and is known to invade the maxillary sinus, its extension by destruction of bone being due either to pressure, as was previously generally believed, or to chemical action of the cholesterol content in the capsule on the underlying bony matrix, as has recently been suggested by Alden.[3] Regardless of which is the actual method of growth, it should be possible ordinarily to show by studies with iodized poppy-seed oil and roentgen rays that the radicular cyst is separate and distinct from the remaining portion of the maxillary antrum. Ewing,[1] in his discussion of radiculodental cysts, made no mention of the presence of a bony capsule but did state that this type of cyst occurs more frequently in

1. Furstenberg, A. C.: A Clinical and Pathological Study of Tumors of the Nose, Pharynx and Mouth of Teratological Origin, Tr. Am. Laryng. A. **55**:128-138, 1933.

1a. Ewing, James: Neoplastic Diseases, Philadelphia, W. B. Saunders Company, 1928.

2. Becker, Erich, cited by Blum, T.: Do All Cysts in Jaws Originate from Dental System? J. Am. Dent. A. **16**:647 (April) 1929.

3. Alden, Arthur M.: The Radicular Cyst Which Invades the Bones of the Face, Tr. Am. Laryng. A. **55**:23-28, 1933.

the upper than in the lower jaw, and he added that the walls of the cyst may be cellular.

The following report concerns a case in which the tumor presented characteristics of both an adamantinoma and a radicular cyst but not all the characteristics of either.

REPORT OF A CASE

Fr. E. S., a seminarian aged 28, was examined first on April 3, 1936, complaining of a swelling behind the upper third molar on the left side from which drainage had persisted since it was incised in a neighboring city four months previously. There was a history of the extraction of the upper second molar on the left side four years before without complications. The swelling referred to appeared two years before examination and disappeared spontaneously after several weeks, recurring about four months before examination, when it was incised. Before the incision, the patient complained of frequent headaches, but these had practically disappeared since. There was no history of frequent colds or of nasal discharge between colds. The patient did, however, have a morning postnasal discharge.

Examination.—A fistula was present from which there was purulent drainage at the apex of the gingival-labial fold, immediately above the anterior aspect of the upper third molar on the left side.

There was moderate congestion of the nasal membranes, with a posterior septal spur on the left, which was in contact with the inferior turbinate. There was also hyperplasia in the middle meatus.

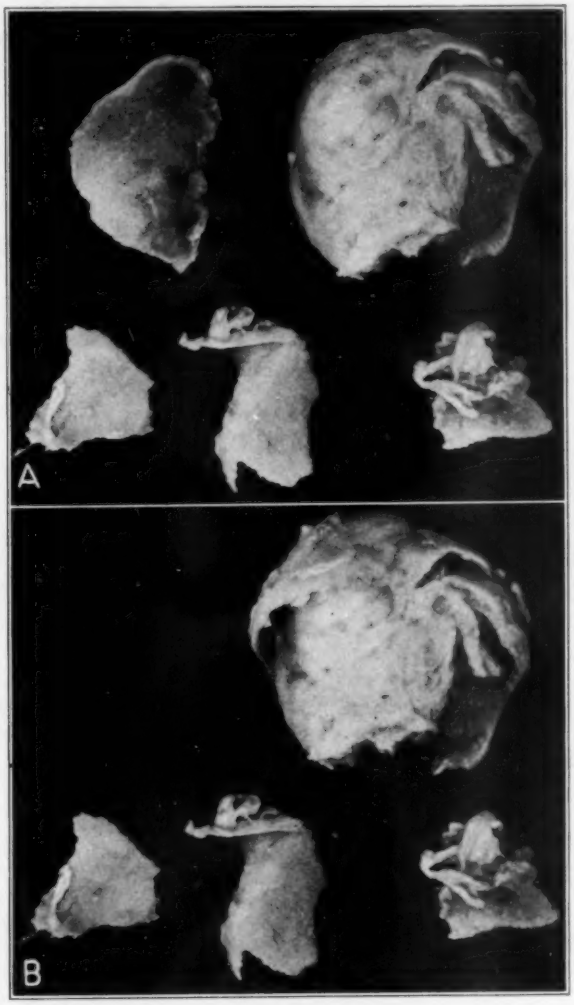
Roentgenograms showed the frontal sinuses, the right ethmoid sinus and the right antrum clear; the left ethmoid sinus hazy, and the left antrum filled with a large circular area of opacity which was apparently a cyst.

Lavage of the left antrum resulted in the release of several clumps of mucopus. Iodized poppy-seed oil was injected, and a subsequent roentgenogram showed only a small amount of it in the region of the canine fossa. In other words, there was an almost complete filling defect.

A culture of material taken from the nose showed a growth of Staphylococcus albus, a few short chains of a nonhemolytic streptococcus, Micrococcus catarrhalis and a few short, thick gram-positive bacilli.

Operation.—On April 30, 1936, a radical operation on the left antrum and an endonasal operation on the ethmoid sinus were performed after the removal of the septal spur. When the soft tissues were incised and elevated, the anterior bony wall of the antrum was opened as for an ordinary Caldwell-Luc operation. Within the bony wall of the antrum, a second thin layer of bone was found, completely filling the antrum cavity and completely surrounding a large fibrous-walled cyst which contained thick, foul-smelling pus. In other words, the cyst was surrounded on all sides by a thin capsule of bone, this osseous capsule having an easily discernible line of cleavage from the wall of the cyst and also from the bony wall of the antrum itself. The only interruption to the structure as described was in the lower outer angle of the antrum, where the underlying bone was eroded in an area the size of a dime, from which there was a draining fistula opening high above the last molar. This area was widely removed. No normal antral mucosa was found at any point. The middle meatal wall was degenerated and was widely removed. Hyperplastic pyogenic membrane filled the entire ethmoid labyrinth, all the cells of which were exenterated. Anterior upwardly displaced ethmoid cells were removed, so as to permit the entrance of a large frontal sound. The anterior wall of the sphenoid sinus was inspected, and as its covering membrane was hyperplastic, the orifice was enlarged and the moderately hyperplastic lining membrane of the sphenoid sinus was removed without curetting.

Course.—The patient's postoperative course was uneventful, except that there was slightly more bleeding than normal, although the bleeding and the coagulation time preoperatively were within normal limits. At no time, however, was the hemorrhage sufficient to cause alarm. Subsequent healing progressed normally, and the patient was dismissed from treatment on June 12, 1936, without complaint.



A, the cyst and four pieces of a thin osseous capsule which had surrounded it. Actual size. *B*, the same as *A* except that the large piece of the osseous capsule had been fitted over the cyst to show their relationship as discovered at operation.

His nose at that time was in excellent condition, and the site of the previous fistula was completely healed.

A report from the department of pathology at the hospital follows:

Pathologic Report.—Specimen from Left Antrum: The specimen consisted of a clean disk of thin bone together with a strip of hyaline cartilage covered with mucous membrane.[4] One surface of the latter was smooth and pinkish white, while the other was a bit roughened and presented a pinkish gray glossy, granular area.

Microscopic examination showed that the strip consisted of dense fibrous tissue lined by several layers of circular epithelial cells. Diffuse round cell infiltration was noted, with some polymorphonuclear leukocytic reaction. There was an increase in fibrous connective tissue. No evidence of neoplasia was present.

The accompanying photographs show the cyst and the osseous capsule except for those portions which were used for sections for microscopic study. They are shown first separately and then with the larger portion of the bony capsule in place to demonstrate its intimate relationship with the cyst wall.

COMMENT

From the history, the changes noted on examination and the findings at the time of the operation, this tumor was unquestionably of dental origin. Its general appearance and structure would fit into the class of adamantinoma except that the tumor did not distort or bulge the normal bone at any point except in the eroded area on the floor of the antrum. The osseus capsule covering the fibrous cyst was, as mentioned, separate and distinct from the normal bony wall of the antrum and appeared to have been laid down as a shell around the cyst as it grew upward. From the preceding history of the removal of the upper left second molar two years before the appearance of the first swelling and from the location and extent of the tumor, it could be classified either as an adamantinoma or as a radiculodental cyst, although, if the latter, it would probably represent an extreme state of growth, since it completely filled the antrum cavity. In view of the presence, however, of the complete osseous capsule, it apparently belongs more properly in the class of adamantinoma, secondarily infected, accompanied by pressure changes in the middle meatal wall and hyperplasia of the ethmoid mucosa. The fact that further bulging and distortion of the normal boundaries of the antrum did not occur is probably due to the notoriously slow growth of this group of neoplasms together with the fact that there had been constant drainage of pus from the fistulous tract which relieved the pressure. This is further borne out by the disappearance of the patient's headache after the establishment of drainage by incision.

2077 Wilshire Boulevard.

4. This was the wall of the cyst proper, already described as extremely fibrous.

ELONGATED STYLOID PROCESSES

Report of Two Cases

WATT W. EAGLE, M.D., DURHAM, N. C.

Most instances of elongated or otherwise abnormal styloid processes that have been reported were observed by anatomists rather than by clinicians. It is probable that numerous cases of elongated styloid processes have been observed and treated by operation when necessary, but relatively few have been recorded.

From the Department of Otolaryngology, Duke University Medical School and Hospital.

The credit for the first authentic report of clinical symptoms with subsequent removal of the styloid process goes to Weinlecher, for a case observed in 1872. Ossification of the stylohyoid ligament, however, had been recorded as early as 1652 by Demanchetis.

The normal styloid process measures between 2.5 and 3 cm. The tip is cartilaginous and is continued over to the lesser cornu of the hyoid bone as a band known as the stylohyoid ligament. Total calcification of this ligament has been observed anatomically. According to Dwight,[1] the styloid process can be divided into four portions. The most proximal, a cuplike portion, is called the tympanohyal; the distal, or stylet, portion of the process proper is called the stylohyal; the ligamentous portion is called the ceratohyal, and the portion of the hyoid cornu to which the ligament is attached is called the hypohyal. Occasionally there appear to be false joints shown by roentgenograms and digital manipulation. These occur at the junction of the stylohyal and the ceratohyal (fig. *A*).

A thorough anatomic study of the styloid process was made by Dwight[1] in 1907, which included anatomic and clinical observations. Roentgenograms of cadavers demonstrated elongated styloid processes, and were the first demonstrating such findings.

A, roentgenogram showing elongated styloid processes. *B*, roentgenogram taken after operation.

An unusually elongated styloid process may cause no symptoms. A slightly elongated one that points medially may cause severe symptoms. The condition may be unilateral or bilateral. From records there seems to be a preponderance among men. Furthermore, the condition seems to be recognized more often in adults beyond the age of 30.

One of the earliest American clinical cases was reported by Stirling,[2] of Atlanta, Ga., in 1896, the patient being his wife. Thigpen in 1932[3] reported eleven cases that he had observed, in some of which he had operated. In the discussion following his paper eight other cases were reported by five of his confrères. This is the largest collection of reported clinical cases.

The symptoms usually arising from elongated styloid processes are localized mainly in the pharynx. A nagging or aching sensation in the throat somewhat

1. Dwight, Thomas: Stylohyoid Ossification, Ann. Surg. **46**:721, 1907.

2. Stirling, A. W.: On Bony Growths Invading the Tonsil, J. A. M. A. **27**:734 (Oct. 3) 1896.

3. Thigpen, C. A.: Styloid Process, Tr. Am. Laryng., Rhin. & Otol. Soc. **38**: 408, 1932.

similar to chronic pharyngitis is most common. Pains may radiate to the middle ear or the mastoid region. Frequently a sensation of a foreign body having lodged in the pharynx is noticed. There may be difficulty in swallowing. Symptoms similar to those of glossopharyngeal neuralgia have been encountered, and such a condition could easily be possible, owing to the proximity of the glossopharyngeal nerve.

Diagnosis is made by digital palpation and roentgenograms. The treatment is accomplished by exposing the styloid process through a pharyngeal approach and biting off with rongeurs the palpable projecting process or, as recommended by Thigpen, the fracture of the process digitally, the fragment being displaced laterally. Elongated styloid processes may be asymptomatic, and no treatment may be indicated. The prognosis is extremely good in all cases. Complications are possible, but they rarely occur. Infection through the operative site could spread into the pharyngeal tissues adjacent to the stump of the styloid process. Osteomyelitis has been feared. Injury to the facial nerve must be considered in attempting to leave a short stump. Ligation of the carotid artery may be difficult.

Two cases of elongated styloid processes are herewith reported of four that have been observed. The two other patients, whose condition was diagnosed, did not return for treatment.

Case I.—M. T., a white woman aged 31, for eight years had pain throughout the left side of her throat that radiated into the left middle ear and the tip of the left mastoid. These symptoms occurred immediately after a tonsillectomy performed with the area under local anesthesia. The history was otherwise entirely without significance. The physical examination gave negative results except for a palpable and elongated styloid process in the left tonsillar fossa. The patient had immediate relief from pharyngeal and aural pain on the left side after operation on Sept. 26, 1935. About 2 cm. of the left styloid process was removed. Unfortunately, roentgenograms were not made in this case.

Case 2.—P. C. was a white man aged 56. Twenty years previous to operation a slight abnormality in swallowing was noticed. He consulted a specialist, who recognized the condition and advised him never to have the tonsils removed because of underlying elongated styloid processes. However, twelve years later (eight years before operation) obstinate generalized eczema developed. After a thorough diagnostic study, the consultants believed the tonsils to be the only definite focus of infection, and tonsillectomy was advised. The styloid processes were easily palpable just lateral to the tonsils and slightly beneath the anterior pillars. Roentgenograms (fig. *A*) showed that both styloid processes were elongated. They were found to be more than 7 cm. in length, including the calcified stylohyoid ligaments. The tonsils were removed without difficulty on June 16, 1936. The processes had caused a deep groove to form on the lateral surface of each tonsil. The styloid process on each side was then partially removed by dissection under guidance of the palpating finger. The bony process removed on the left side measured over 2 cm. with a considerable amount of stylohyoid ligament attached, and the bony process removed on the right side measured 3.5 cm. with a small portion of the stylohyoid ligament attached (fig. *B*). Although the postoperative roentgenograms showed styloid processes of normal length, they could not be palpated even as stumps during the operation. This patient had few symptoms relative to the elongated styloid processes, but their removal was necessary because tonsillectomy had exposed them in the tonsillar fossae.

SUMMARY

The cases of two patients with elongated styloid processes who were operated on are reported. Four such cases have been observed. In one of the cases reported the abnormality was bilateral and in the other unilateral. In the latter pharyngeal symptoms were severe for eight years, while in the case of bilateral abnormality symptoms were almost minimal during a twenty year period. Preoperative and postoperative roentgenograms are shown to demonstrate the bilateral abnormality. Surgical removal of the elongated processes relieved all symptoms.

Abstracts from Current Literature

Ear

REMARKS ON GRADENIGO'S SYNDROME AND PETROSITIS. R. B. LUMSDEN, J. Laryng. & Otol. **51**:150 (March) 1936.

Lumsden reviews the present state of knowledge regarding Gradenigo's syndrome and petrositis. He examined the records of the Edinburgh Royal Infirmary since 1927 and found five cases of Gradenigo's syndrome; three of the patients recovered and two died. In addition to this he is able to report four other cases, of which two terminated fatally. Before giving his attention to these nine cases, he discusses the present state of knowledge regarding infections of the apex of the petrous bone.

In considering the nine cases of Gradenigo's syndrome, he says that the onset occurred before operation in two and after operation in seven. In every case it occurred in connection with acute mastoiditis. The author also presents an analysis of seventy-eight published cases, all of which presented either (1) the atypical Gradenigo syndrome or (2) in the absence of paralysis of the sixth nerve, other evidence of petrositis, the presence of which was proved by roentgenograms, operation or postmortem examination. Fifty-one patients recovered, and twenty-seven died. The onset of symptoms and signs occurred before operation in twenty-one.

In conclusion Lumsden adds that while Gradenigo's syndrome is well known to otologists, they are as yet not sufficiently familiar with the clinical picture of petrositis. In the absence of paralysis of the sixth nerve, the making of such a diagnosis would appear to present considerable difficulty. It would be well to bear in mind the possible presence of petrositis in those cases in which the symptoms are unusually slow in clearing up after an adequate Schwartze operation. A consideration in retrospect might result in a fuller appreciation of the significance of unilateral headache and slight rises of temperature occurring in such cases during the postoperative period. Roentgen examination, especially by vertical projection, would appear to offer valuable assistance once suspicions are aroused. Thus, the otologist may arrive at a decision to carry out further operation and so possibly avoid the late onset of meningitis, which occurs unexpectedly from time to time. Reports of seven cases which have not previously been recorded are appended.

EDITOR'S ABSTRACT.

ANATOMICOCLINICAL SYNDROME OF TUMORS OF THE FOURTH VENTRICLE FROM THE OTONEUROLOGIC POINT OF VIEW. G. S. ZIMMERMANN and A. S. TCHERNYSCHEW, Rev. d'oto-neuro-opht. **14**:29 (Jan.) 1936.

A tumor of the fourth ventricle is manifested by local and remote symptoms, the latter by reason of the enormous hydrocephalus. Of the local symptoms, pathologic phenomena of the eighth nerve occupy first place; disturbances of the cochlear division are more rare than those of the vestibular. The clinical and anatomicopathologic aspects depend on the stage of evolution at the time of examination.

The case reported is that of a boy aged 14, whose symptoms had begun two years before with headaches, followed by attacks of vertigo. Ten weeks before death he became blind, owing to atrophy of the optic nerve following papillary stasis. Good hearing, with shortened bone conduction, spontaneous deviation inward of the arms and a Romberg sign (falling backward) were observed. Postrotatory horizontal nystagmus of large amplitude toward either side and inverse past pointing were elicited. Tests for falling and past pointing after douching gave normal results. No localizing diagnosis was made. At autopsy a tumor was noted on the ventral surface of the brain, between the cerebellum and

the medulla. The tumor (perithelioma) compressed the right tonsil of the cerebellum and the median parts of the biventer and the gracilis lobe on both sides and filled the fourth ventricle, compressing the dorsal part of the pons, the tonsils and the tuber vermis. Microscopic examination of serial sections revealed no degeneration of the ventral and dorsal cochlear nuclei. The cells of the nuclei of Deiters, Bechterew and Schwalbe were degenerated, and the glia was proliferated. Degenerative changes were present also in the nucleus of Roller bilaterally, the fibers of the nucleocerebellar tract, the cells of Purkinje, the lingual and central lobes, the pyramid, uvula, nodulus and biventer and gracilis lobes and all the central cerebellar nuclei. The indemnity of the cochlear nuclei is explained by the fact that they are situated more deeply in the floor of the ventricle than the vestibular nuclei. The spontaneous inward deviation, the inverse deviation after stimulation and the nystagmus of wide amplitude were caused by disturbances of function of the nucleocerebellar fibers, the function of which is inhibitory. From the fact that correct falling occurred in the caloric test in the presence of the alterations observed, the authors conclude that: (1) the pathway of the falling reaction does not necessarily pass by way of the vermis and (2) the static disturbances (falling backward and staggering gait), associated with a correct falling reaction to stimulation of the labyrinth, are due exclusively to changes in the vermis.

DENNIS, San Diego, Calif. [ARCH. NEUROL. & PSYCHIAT.]

NYSTAGMUS AND LATENT TENDENCY TO NYSTAGMUS. E. WIRTH, Arch. f. Ohren-, Nasen- u. Kehlkopfh. **140**:327, 1936.

Wirth points out that vestibular rhythmic jerking nystagmus is an important sign of an organic disturbance of the vestibular nerve. However, it is difficult to recognize this type and to differentiate it from other types. The author emphasizes that it is advisable to search for a latent tendency to nystagmus. He shows that the simple head-shaking, bending and postural experiments are well suited for this purpose. The nystagmus that is elicited by shaking, bending or changes in the position is often the only objective sign of organic impairment of the vestibular nerve. The author proves this by several case histories and emphasizes that these tests should never be omitted if a patient complains of attacks of vertigo. Caloric and rotatory tests likewise reveal a latent tendency to nystagmus. However, the author shows that erroneous conclusions are possible. He also emphasizes that the weak stimuli are better suited for the detection of a latent tendency to nystagmus as well as for the detection of other vestibular disturbances than are strong stimuli.

EDITOR'S ABSTRACT.

HYDROCEPHALUS AND THE INTERNAL EAR. L. KRAUS, Hals-, Nasen- u. Ohrenarzt (Teil 1) **27**:64 (March) 1936.

Kraus reports a case of deaf-mutism with hydrocephalus in a man who had had these defects since birth and who died at the age of 61. The author describes the results of the postmortem examination and particularly the histologic studies on the ears. The most noteworthy observations on the internal ear were (1) vesicular dilatation and displacement of the contents of the perivascular and perineural lymph spaces of the modiolus of the cochlea, (2) a deficient development of the vestibular portion of the ductus cochlearis and (3) the sheathing of Corti's membrane with a nucleated covering. The author assumes that mild intra-uterine serous meningitis resulted in the hydrocephalus and in serous labyrinthitis. The latter caused the deformities and the inflammatory changes in the internal ear. The continuous pressure on the brain resulted in the dilatation of the lymph spaces. Thus, the defects are the result of serous inflammation, which took place while the internal ear was still in the stage of development.

EDITOR'S ABSTRACT.

THEORY OF HEARING AND GALVANOTHERAPY ON THE BASIS OF AFTER-IMAGES AND ELECTRICAL NERVE PHENOMENA. E. KUPFER, Klin. Wchnschr. **14**:506 (April 6) 1935.

Kupfer refers to previous publications on this subject (*Monatschr. f. Ohrenh.* **68**:767, 943, 1041, 1208, 1294 and 1462, 1934) in which he demonstrated that the after-images of all senses are subject to the same law, and that the cause seems to be electrical. It appeared that an electrochemical process goes parallel to the subjective phenomena of stimulus and after-image. The author reasons that if stimulus and after-image are only the phenomenal manifestation of to-and-fro-moving electrochemical processes it should be possible to elicit these phenomena by electrical currents. This is actually the case, but there is evidence that a chemical component is likewise involved. A satisfactory theory of hearing should demonstrate how internal pulsating currents are elicited by chemical action.

The ear is a double apparatus in which, after transformation in the middle ear, the longitudinal waves of the lymph are changed in some manner into transverse movements on the hair cells.

The assumption of a sharp resonance with transverse waves of the hair cells is untenable. Moreover, the results of the author's galvanic experiments indicate the development of electrical stimulus currents, and these in turn call not for a mechanical but rather for a chemo-electric regulation in the fibers and the lymph. Nowhere in the sense organs is there an elicitation of stimulus or current merely by mechanical means, without interposition of a chemical process. Moreover, the so-called central waves, the rotary tones of von Hornbostel, as well as the observations of Wever and Bray on the auditory nerves of animal preparations, the reaction frequencies of which conform to the stimulus frequencies, require an internal current stimulus that runs synchronously to the tone stimulus; that is, a synchronous ionic effect of the lymph. The question is how does this stimulus come about?

In the auditory organ there is a contact and sliding system of a solid and a fluid phase. Between the solid parts that protrude into a fluid and this fluid itself, there exists a difference in potential, the xi potential. In the ear the requirements for the development and function of this potential are given in so far as there are hair cells which protrude into the lymph, the surface of which must load itself against the potential of the fluid. As always on the border between solids and fluids, there exists an electrical double layer with opposite charges.

The author points out that Wever and Bray succeeded in deriving from the auditory organ of cats after tone stimulation frequencies that were synchronous with the oscillations of the tone. If the principle underlying this observation is the electrochemical one described by the author, it should be reproducible outside the organism in an inorganic model. The author states that this has been done, quotes the description and reproduces a picture of the apparatus, as given in the original report of O. Voss.

The manner in which the extremely small energies are biologically amplified was explained by Fürth in 1929.

The cochlea acts neither as an amplifying nor as a differentiating apparatus nor as a type of stringed instrument, but simply as an electrical elicitation apparatus or better as a "stimulus transformer," which the author defines as an organ in which the incoming mechanical movements are transformed into electrical nerve currents.

In the last part of his paper the author gives his attention to galvanotherapeutic measures that could be deduced from these experiments. EDITOR'S ABSTRACT.

A STEREO-ENDOSCOPE FOR THE EXAMINATION OF BODY CAVITIES. H. ADLER, Monatschr. f. Ohrenh. **70**:37 (Jan.) 1936.

Adler says that during the winter of 1934 and 1935 pneumonic or intestinal influenza of nurslings and small children was frequently accompanied by insidious otitis. Otoscopic examination usually revealed a tympanic membrane of normal

color without protrusion. The question whether otitis media existed was difficult to solve, because the fever and other symptoms might be the result of the internal disorders. Paracentesis was usually followed by slight suppuration and a reduction of the fever, but because of renewed increases in temperature, it had to be repeated several times or complications would result.

Because of the narrow external meatus, it was difficult to detect minimal changes of the tympanic membrane, and Adler decided that a stereoscopic observation of the tympanic membrane was necessary in these cases. The usual stereoscopic glasses were unsuitable for the examination of the tympanic membranes of nurslings and small children, and Adler had to construct an instrument that would permit the inspection of extremely narrow cavities. He describes how he arranged the prisms and also how he solved the problem of illumination. He says that his apparatus is so light that it can be attached directly to glasses, and for persons who do not wear glasses it can be attached to empty frames. He gives an illustration of the apparatus. He says that this is only a preliminary report, for his experiences with the device are not yet sufficient to warrant a final evaluation. He hopes also to improve further the construction of his stereoendoscope.

EDITOR'S ABSTRACT.

INFLUENCE OF CORTICAL INNERVATION ON LABYRINTHINE NYSTAGMUS. H. BRUNNER, Monatschr. f. Ohrenh. **70**:40 (Jan.) 1936.

Brunner says that the observation made by Kümmel and Jansen, that the voluntary looking in the direction of the rapid component of the nystagmus increases it, whereas looking in the direction of the slow component inhibits it, is one of the generally recognized laws of nystagmus. However, he directs attention to the fact that the spontaneous nystagmus which develops in acute disease of the brain stem or during a stage of large cerebellar tumor and which is probably elicited by a disorder in the vestibular tracts and nuclei does not always follow this law or may even behave directly contrary to it. Brunner describes observations on three patients with cerebral tumor. He finds that he is able to corroborate the observations of other authors, namely, that in frontal and frontotemporal tumors, there may appear instead of caloric nystagmus a deviation of the eyes in the direction of the slow component of the nystagmus. But there remains the problem as to why this is not observable in all cases of frontal and temporal tumor. He discusses this problem but concedes that his theory is only a hypothesis which has to be supported, modified or disproved by further studies.

EDITOR'S ABSTRACT.

CONSERVATIVE TREATMENT OF PERFORATION IN OTITIS MEDIA. R. ZEIDLER, Wien. klin. Wchnschr. **49**:914 (July 17) 1936.

Zeidler has adapted an apparatus invented by Seidner for use in the treatment of otitis media that has perforated. The apparatus consists of a double metal tube with two branches, an air pump worked by a jet of water, a stand with a container for medicaments and two rubber tubes. One wide branch of the double metal tube is connected with the pump, and the other branch, with the container. The pump, which can exert a suction equivalent to 76 cm. of mercury, can be mounted on a water faucet. The end of the metal tube which is opposite the branched end is placed in the ear of the patient after it has been covered with an appropriate perforated rubber plug. The pump is started, and the pressure within the ear is lowered. Through one branch of the tube the irrigating solution flows into the ear, and through the other branch it is sucked out. There is thus a continuous flow.

Over a thousand patients have been treated by this method. The first attempts were made on those with chronic otitis media and large perforations. Later, the treatment was extended to those with acute disease and spontaneous or artificial perforations (paracentesis). Finally, all patients with nonoperative otitis media

were treated. Of the more than a thousand patients, 21 per cent had acute otitis media. In most of these patients the treatment was strikingly successful. The pain disappeared immediately, and the temperature sank. Others required longer treatment (from two to four weeks, with three or four treatments a week).

Zeidler claims that this method of treatment provides adequate cleansing and drainage. It is not painful and not dangerous. There were no untoward incidents. The apparatus is inexpensive and easy to handle.

ABT, Chicago. [AM. J. DIS. CHILD.]

CHRONIC SINUS THROMBOSIS. H. GERLACH, Ztschr. f. Hals-, Nasen- u. Ohrenh. **39**:262, 1936.

The symptoms in the cases reported by Gerlach deviate in many respects from those usually noted in sinus thrombosis. The course is not acute but often extends over weeks without the characteristic fever curve. This form of sinus thrombosis, which the author designates as chronic, stands between the benign (nonfebrile) and the acute form, which has a tendency to spread rapidly. Chronic sinus thrombosis is characterized by intermittent fever, by slow but extensive progress of the thrombotic process within the system of the cerebral sinuses and by a tendency to organizatory transformation. The spreading of the thrombosis takes place also during the nonfebrile intervals and is interrupted by several attacks of fever and chills, which may appear at intervals of from one to three weeks. These occasional attacks of chills are frequently the only visible signs in a long period of almost complete freedom from symptoms. As a rule, chronic sinus thrombosis, if it does not terminate in cure, extends over a period of three or four months. The author points out that Ruttin designated this course as intermittent progressive sinus thrombosis, whereas Langenbeck speaks of a chronic or a subacute course. The latter author describes a case in which there were symptoms similar to those in the last case observed by Gerlach. Here too the process was prolonged and benign and was interrupted by long nonfebrile intervals. An operation was performed, and the patient recovered.

EDITOR'S ABSTRACT.

Pharynx

ARTHUS' PHENOMENON IN OROPHARYNGEAL MUCOSA. K. ARSLAN, Arch. ital. di otol. **48**:18 (Jan.) 1936.

Arslan succeeded in producing Arthus' phenomenon in the velum pendulum palati of rabbits by means of submucous velar injections of horse serum, repeated at regular intervals. The development of Arthus' phenomenon is slower in the oropharyngeal than in the submucous tissues of rabbits, and the oropharyngeal lesion is smaller than the subcutaneous lesion. These facts are probably due to a diminished reactivity of the submucous tissues to local sensitization compared to that of the subcutaneous tissues. The velar histogenous reaction is different from that caused by chronic processes of inflammation or irritation of the mucosa due to stimulation and repeated trauma. The same experiments carried on in guinea-pigs failed to produce Arthus' phenomenon in the oral mucosa of the animals. The failure confirms the opinion that guinea-pigs are refractory to the development of reactions of local anaphylaxis. The success in producing Arthus' phenomenon in the oropharyngeal mucosa of rabbits shows that the mucosa of the upper part of the respiratory tract reacts to the heterogenous substances with which it comes in contact. This fact is of imporatnce for further investigation of the relation between the upper part of the respiratory tract and the production of phenomena of humoral or histogenous anaphylaxis. The results of the experiments do not interfere with the nature of Arthus' phenomenon, which may be a reaction of local anaphylaxis or of a specific sensitivity of the tissues to heterogenous substances.

EDITOR'S ABSTRACT.

POSTOPERATIVE TONSILLITIS. R. GESSNER, Hals-, Nasen- u. Ohrenarzt (Teil 1) **27**:35 (March) 1936.

In the material analyzed by Gessner postoperative tonsillitis occurred after 189 of 4,143 surgical interventions, that is, in 4.56 per cent. In the majority of the cases (70.3 per cent) tonsillitis developed after operation on the nose and the accessory sinuses. If tonsillectomy is done simultaneously with the nasal intervention, the possibility of posttraumatic angina is considerably reduced. The author observed also that among the patients who were alone or in a room with only one other person, postoperative tonsillitis was much less frequent than among those who were in wards with a large number of patients (1.5 per cent compared to 5.2 per cent). This proves not only the exogenic origin of most postoperative tonsillitis but also the advisability of isolation to prevent these disorders.

EDITOR'S ABSTRACT.

AGRANULOCYTOSIS. K. O. MARCKSTADT, Ztschr. f. Hals-, Nasen- u. Ohrenh. **39**:303, 1936.

In remarks about the symptomatology of agranulocytosis, Marckstadt emphasizes the similarity to severe septic infections and shows that for diagnosis a careful examination of the blood is indispensable. He then describes and discusses six cases. The anamneses of these patients reveal, like the reports of other investigators, that earlier the patients had had such disorders as polyarthritis rheumatica, nephritis, tonsillitis, syphilis, eczema and ventricular ulcer, which apparently have a predisposing influence, for it is now generally accepted that diminished resistance or sensitization of the organism is a prerequisite for the development of agranulocytosis. The onset of the disease is usually acute and is accompanied by the sudden appearance of high temperatures and chills. In two of the reported cases the onset was more slow. The necrotizing processes in the oral and pharyngeal cavities were always the outstanding symptoms.

After a discussion of the behavior of the blood pictures, the author says that the casting off of the oral and pharyngeal necrosed tissue begins when the granulocytes commence to reappear in the blood. In four of the author's six cases there was a fatal outcome, death taking place on the third, seventh, eighth and nineteenth days, respectively. The last case was one of those in which the onset was rather slow.

The prognosis is always doubtful. The degree of leukopenia, the extent of the necrosis and the general condition or the height of the fever, permit no conclusion regarding the probable outcome. However, it appears that a chronic course permits a more favorable prognosis than does an acute one. Survival beyond the first week justifies a certain hopefulness. Moreover, it must not be overlooked that spontaneous recoveries as well as relapses are possible.

In the treatment of agranulocytosis various therapeutic substances, such as neoarsphenamine, a mixture of chiniofon and casein, and gold preparations, have been tried without convincing success. Injections of solutions of sodium chloride (10 per cent) and of alcohol (30 per cent) seem to have had a slightly better, but not a satisfactory, result. Regarding the value of blood transfusions and of roentgenotherapy, the opinions are likewise divided. Since spontaneous remissions have repeatedly been noted following abscess formation, the artificial production of abscesses by means of turpentine has been tried to stimulate leukopoiesis, but here too the effect was not convincing. Better results were obtained with pentnucleotide, which was first used in America. The author places high hope in liver therapy also.

EDITOR'S ABSTRACT.

PREVENTION OF TONSILLOGENIC SEPSIS BY ABSCESS TONSILLECTOMY. A. LINCK, Ztschr. f. Hals-, Nasen- u. Ohrenh. **39**: 329, 1936.

Linck says that in a previous report he designated peritonsillar abscesses as the precursors and forerunners of tonsillogenic sepsis. He admits that this point of view contradicts that held by most other authors, who consider the peritonsillar abscesses as entirely benign complications of acute inflammation of the throat and therefore

restrict themselves to a minimum of therapeutic measures, an expectant attitude and incision. The author thinks that such a stand cannot be defended in view of the serious rôle played by peritonsillar abscesses in the development of tonsillogenic sepsis. He demands abscess tonsillectomy for all cases of manifest or regressing peritonsillar abscess and in all cases in which peritonsillar inflammation or phlegmon seems probable. To be sure, he admits that peritonsillar abscesses have been known to develop after tonsillectomy (not abscess tonsillectomy). However, it has been proved that such abscesses were usually caused by remaining and inflamed tonsillar remnants. Moreover, he is convinced that in abscess tonsillectomy, in which the tonsillar base is softened and loose, the persistence of remnants is much less likely than in tonsillectomy that is done during the interval, when the capsule is tightly connected, perhaps even by adhesions.

It is further pointed out that the peritonsillar abscesses are not always single or repeated disease processes, which, after having taken their course, subside completely, but are often phases of a continuous process. On the basis of case reports, the author discusses the various phases and shows that the first phase, that of localization, is the best for the prophylactic treatment of tonsillogenic sepsis by means of abscess tonsillectomy.

EDITOR'S ABSTRACT.

Larynx

RESPONSE OF A RETROLARYNGEAL INFECTION TO X-RAY THERAPY. HAROLD R. ROEHM, Arch. Pediat. **53**:348 (May) 1936.

Roehm reports a case of retrolaryngeal infection occurring in a boy 9 years of age. The diagnosis was made from a lateral roentgenogram of the cervical portion of the spine, which showed a marked thickening of the retrolaryngeal tissues, with a forward displacement of the larynx, trachea and esophagus, extending to the seventh cervical vertebra.

A blood transfusion and two roentgen treatments produced marked improvement.

ORR, Buffalo. [AM. J. DIS. CHILD.]

MEMBRANE FORMATIONS ON THE VOCAL CORDS. G. HOFER and T. MOTLOCH, Monatschr. f. Ohrenh. **70**:576 (May) 1936.

Hofer and Motloch point out that membranous deformities of the vocal cords occur chiefly on the anterior commissure but occasionally also on the posterior commissure of the vocal cords. They vary in size from a slight web formation to complete atresia of the lumen. However, they usually do not impair the motility of the vocal cords. The extent of the adhesion determines the patency of the larynx. The genesis of these membranes has not been completely explained, but some authors regard them as embryonal remnants. To be sure, the membranous deformities are not necessarily congenital, for there are a number of disorders that may cause the formation of cicatricial membranes in the region of the glottis. In this connection the authors mention syphilis, diphtheria, tuberculosis, typhoid perichondritis, leprosy, rhinoscleroma and glanders.

In giving their attention to the treatment of the membranous deformities of the vocal cords, the authors first review a method described by Haslinger in 1923, which, however, proved satisfactory only in some cases. Further, they report a case of their own observation. The patient was a boy aged 14, whose anamnesis revealed measles and diphtheria and hoarseness since the attack of diphtheria, but he had had a predisposition to hoarseness even before the attack of diphtheria. Indirect laryngoscopy revealed a membrane reaching from the anterior commissure to the vocal process. The membrane was at the level of the vocal cords and extended between them and left only an opening of the width of a lead pencil. With deep inspiration, breathing was considerably inhibited and there was stridor. The membrane was divided by cautery, but in spite of careful after-treatment, it grew again. A median tracheotomy was made, and a cannula was introduced. After the tracheotomy wound had cleared up, an attempt was made to hold the vocal cords apart (by means of a bolt) after the division of the

membrane. Since this attempt failed, a new bolt was used into which a plate had been built, which would enter into the anterior commissure. This method produced the desired result, so that it was possible to let the tracheostoma close again. In the discussion of the case, the authors describe the construction and operation of the special bolt they used and suggest that their method may be used in similar cases.

EDITOR'S ABSTRACT.

Nose

THE DEVELOPMENT OF THE ACCESSORY NASAL SINUSES. H. RICHTER, Arch. f. Ohren-, Nasen- u. Kehlkopfh. **141**:54, 1936.

Richter directs attention to a report about the normal development of the human nose, particularly of the ethmoid bone, which he published in 1932. He arrived at the conclusion that in the temporal bone as well as in the accessory nasal sinuses, the stimulus for the pneumatization goes out from the mucous membrane. He speaks of a pneumatizing power of the mucous membrane and points out that he himself and M. Schwarz demonstrated the fundamental significance of the pneumatizing power of the nasal mucous membrane for the development of the accessory nasal sinuses. Sitsen, who studied the structure and the development of the frontal sinus, however, arrived at the conclusion that the mucous membrane does not take part in the pneumatization.

Because Sitsen failed to mention Richter's studies, and since Richter gave particular attention to the processes in the mucous membrane and to those of the adjoining bones, that is, to the process of pneumatization, he decided to analyse Sitsen's report. He emphasizes that the accessory nasal sinuses appear in the fetus at different times. The maxillary sinus and the first traces of the ethmoid cells (cribral pockets) and of the sphenoid sinus appear first. The later frontal sinus is one of those cribral pockets which develop as a protrusion of the median nasal duct. Since the frontal sinus is originally a cribral pocket, its origin and development are therefore essentially the same as those of the other cribral pockets and of the other accessory sinuses. Richter chose the ethmoid sinus for his studies for dimensional reasons, but he says that there is no reason to assume that the development of the frontal sinus has a different origin. In his earlier report he demonstrated that the ethmoid cells develop by the active ingrowth of nasal epithelium into the embryonal connective tissue. The presence of the cartilaginous nasal capsule does not prevent the further development of the hollow spaces. On the contrary, a resorption of the cartilage takes place. The basin-like resorption of the cartilage results in long cartilaginous protrusions, which become septums of some of the ethmoid cells. Ossification sets in later. The author emphasizes that all these processes take place before birth, that is, at a time when air pressure is out of the question. The author regards the growth of the ethmoid sinuses during childhood as the result of the new formation of bone on the outer surface of the bony cellular wall and of the resorption of bone on the inner surface. This process begins during the seventh fetal month. He states further that it can be demonstrated that the frontal sinus is derived from the ethmoid bone. He admits that for the period after birth he cannot definitely deny the influence of the external air pressure on the growth of the accessory nasal sinuses, but he feels that neither can such an influence be definitely proved. However, he insists that there is definite proof that the development of the accessory nasal sinuses is the result of a formative power in the mucous membrane.

EDITOR'S ABSTRACT.

ROENTGENOLOGIC EXAMINATION OF THE MAXILLARY SINUS AFTER THE INJECTION OF A CONTRAST MEDIUM. K. BARMWATER, Hals-, Nasen- u. Ohrenarzt (Teil 1) **27**:5 (March) 1936.

Barmwater shows that the technic of roentgenoscopy of the accessory sinuses, particularly of the maxillary sinuses, is in need of improvement. He enumerates some of the shortcomings and points out how these can be avoided by filling with

a contrast medium. After describing the technic which he devised for the contrast filling, he describes his experiences with this method. In summarizing his observations he states that the method is in many respects a valuable supplement to ordinary roentgenoscopic examination. In a veiled maxillary sinus it reveals whether the mucous membrane is normal or thickened, so that suspicion of sinusitis can either be proved false or corroborated. In cases in which the sinus is not veiled and the irrigating fluid at puncture is clear but in which sinusitis is nevertheless suspected, a thickened mucous membrane corroborates the diagnosis of sinusitis. Diffuse, mistlike veiling indicates that the maxillary sinus is filled with polyps. Defects in the wall of the maxillary sinus and the outlines on the whole are more clear with contrast filling than with the ordinary roentgen picture. Contrast filling reveals also whether a tumor of the upper jaw has grown into the maxillary sinus. Moreover, repeated filling with a contrast medium at suitable intervals reveals the effect of roentgen irradiation on tumors of the maxillary sinus. Cysts in the maxillary sinus are likewise clearly demonstrated by means of a contrast medium.

EDITOR'S ABSTRACT.

ETIOLOGY OF CONGENITAL DEFORMITIES OF THE NASAL SEPTUM. H. RICHTER, Hals-, Nasen- u. Ohrenarzt (Teil 1) **27**:53 (March) 1936.

Richter advances evidence to the effect that congenital bending of the nasal septum is frequently a result of the primary enlargement of one or several of the nasal conchae. He points out that such hyperplasias of the nasal conchae occur during the embryonal period, he himself having made observations on human embryos which indicate this. He thinks that such hyperplasia of the nasal conchae may be of inflammatory or other origin.

EDITOR'S ABSTRACT.

HEREDITY OF OZENA. H. REICHARDT, Monatschr. f. Ohrenh. **70**:389 (April) 1936.

Reichardt reviews the literature on the problem of inheritance of ozena and reports studies on twenty-seven families in which ozena occurred. His conclusions are based only on the patients examined. Anamnestic reports about absent members were disregarded in the evaluation, but in the family trees they were recorded in brackets. The diagnosis was based on the following symptoms: atrophic, smooth mucous membrane, great dryness, wide nasal cavity, greenish yellow crusts and fetid odor. In the twenty-seven families examined there were 192 persons. Ozena or simple atrophic rhinitis was observed in 56.3 per cent. Of the diseased persons, 72.2 per cent had simple atrophic rhinitis and 27.8 per cent had the fetid form. The author cites evidence which indicates that there is no essential difference between atrophic rhinitis and ozena. Not the fetor, but the atrophy of the mucous membrane is the essential factor in the disorder.

In the summary the author stresses (1) the observations at his clinic largely correspond to those at other clinics, (2) the probability that the condition is inherited as a dominant mendelian characteristic and (3) the idiotypical character of simple atrophic rhinitis. He points out that although from the scientific point of view it is gratifying to learn more about the nature of the disorder, from the standpoint of the physician it is somewhat discouraging, for if the disease is constitutional, etiologic therapy is impossible and there remains only to influence the symptoms in such a way that the patient will be able to follow his occupation and to live among his fellow-men without causing offense.

EDITOR'S ABSTRACT.

DIAGNOSTIC AND THERAPEUTIC INVESTIGATIONS ON SCLEROMA. E. NEUBER, Ztschr. f. Hals-, Nasen- u. Ohrenh. **39**:281, 1936.

It is pointed out by Neuber that the specific allergic reactions for scleroma as well as the specific therapy were long neglected, for although Bacillus rhinoscleromatis was discovered as early as 1882, its pathogenicity was long doubted and it was regarded as a saprophyte. However, in 1909, specific complement-fixing

substances were discovered in the blood of patients with scleroma. This proved not only that B. rhinoscleromatis is actually the cause but also that scleroma is not merely a local but rather a systemic disorder. In later complement fixation and agglutination experiments, the author proved that the bacillus producing scleroma differs from other capsulated organisms, from the bacillus producing ozena and from the Friedländer bacillus.

After having proved by serologic methods (complement fixation and agglutination) that the scleroma bacillus represents a special form even within the group of the capsulated bacilli, the author decided to study the specific allergic reactions. The first requirement for such reactions is the reliability of the antigen. The author succeeded in producing an antigen that can be used both for allergic reactions and for the specific therapy. In evaluating the allergic reactions, he says that the percutaneous method is valueless but that the intracutaneous method gives the most exact specific reactions. To be sure, some patients with the clinical and serologic signs of scleroma gave a negative allergic reaction, but these were patients who, as the result of prolonged illness, had lost their reactivity, that is, they had become anergic.

The author found that gold preparations are best suited to bring the anergic patient with scleroma from the anergic phase again into the positive phase, in which the allergic reactions once more become positive. The allergic reactions have diagnostic significance, particularly if the disease process is in the deeper air passages. In recent times the author has come to treat every patient with scleroma first with intramuscular injections of gold preparations until a total dose of from 3 to 5 Gm. has been reached. After a short pause of approximately a week, the vaccinotherapy is begun. The injections of vaccine are given at intervals of four or five days, the total number of injections varying between ten and fifteen. As the initial dose, the author takes that quantity of vaccine which has elicited a noticeable allergic reaction in the patient with scleroma. The doses are increased in such a manner that every succeeding injection elicits a local cutaneous reaction. If one series of treatments (gold and vaccine) does not produce the desired results, a new series is given after an interval of from four to eight weeks.

EDITOR'S ABSTRACT.

Miscellaneous

MECHANISM OF SWALLOWING. K. HEGNER, Arch. f. Ohren-, Nasen- u. Kehlkopfh. **140**:387, 1936.

In studying the mechanism of swallowing by means of the laryngeal mirror Hegner was able to corroborate Grahe's observation that foods enter the esophagus laterally from the epiglottis. He differentiates between "pure swallowing" and "masticatory swallowing." He designates as pure swallowing the deglutition of foods that do not require chewing, and he applies the term masticatory swallowing to the deglutition that follows mastication. He first gives his attention to masticatory swallowing. He found that in the majority of cases the food passes on both sides of the epiglottis but that the greater quantity passes as a rule on the side on which the person chews (chief route of swallowing), and the smaller portion passes on the other side (accessory route of swallowing). If a person chews for years habitually on one side, the uvula deviates to the opposite side, so that the palatine arch becomes somewhat enlarged on the side habitually used for chewing. The retching stimulus seems to be reduced on the side of chewing. The right side seems to be more often preferred in unilateral chewing than the left side. Neither surface anesthesia of the mucous membrane of the hypopharynx nor a changed position of the body influences the route of swallowing. The more solid the food is, the greater is the tendency that the larger portion of the food passes chiefly on one side, whereas in case of the more fluid foods, the passage is more bilateral. In regard to pure swallowing the author says that its route is influenced by the unilateral chewing in that it follows the chief route. A number of persons

are capable of influencing the route in "pure swallowing" at will, and some are able to tell on what side they do swallow. In the last part of his discussion Hegner gives attention to the closure of the larynx. He gained the impression that the epiglottis leans backward into the pharynx, somewhat like a roof over which the foods glide toward the right or the left into the valleculae. Underneath the epiglottis, the aryepiglottic folds meet and close the larynx. To be sure, this closure is usually somewhat incomplete, for particles are occasionally found on the laryngeal side of the epiglottis and on the aryepiglottic folds.

EDITOR'S ABSTRACT.

CURED AGRANULOCYTOSIS. A. JAUERNECK, Hals-, Nasen- u. Ohrenarzt (Teil 1) **27**:32 (March) 1936.

Jauerneck reports the clinical history of a woman aged 34 who had severe agranulocytosis. The granulocytes were completely lacking, and there were only 375 leukocytes per cubic millimeter. The anamnesis revealed that she had been addicted to the use of sleeping powders. She became suddenly ill with pains in the joints and in the throat and with high fever. The glands at the angle of the jaw were swollen, and there were ulcerations on both tonsils and their surroundings. She was given twice daily an intramuscular injection of 10 cc. of pentnucleotide, until a total of 120 cc. had been given. After that, a preparation similar to pentnucleotide was given. In addition to this medication, she received roentgen irradiation of the long tubular bones. Under the influence of this treatment, the white cell picture of the blood and the general condition improved. She was discharged as completely cured.

In discussing this case, the author points out that use of aminopyrine has been known to result in agranulocytosis. In view of the fact that some of the medicaments which the patient had been in the habit of taking contain aminopyrine, such a cause is likewise probable in this case.

EDITOR'S ABSTRACT.

RESULTS OF BILATERAL CALORIZATION IN CASES OF TUMOR OF THE BRAIN. H. BRUNNER, Monatschr. f. Ohrenh. **70**:257 (March) 1936.

Brunner says that since 1928 he has used bilateral calorization in patients with tumor of the brain. He describes the technic and then gives a tabular report of the results he obtained in seventy-three patients, of whom twenty-eight had infratentorial tumor and forty-five supratentorial tumor. The table reveals that the bilateral calorization produces positive results in the majority of instances of infratentorial tumor, whereas in the majority of instances of supratentorial tumor it produces negative results. The author discusses these results.

EDITOR'S ABSTRACT.

TACHYLALIC DEFECT AND ITS TREATMENT. D. WEISS, Monatschr. f. Ohrenh. **70**: 341 (March) 1936.

Weiss discusses a speech defect, in which often, but not always, the words are uttered with great rapidity (tachylalia). Other symptoms are as follows: frequent repetition of words and syllables, omission and contamination of words and syllables, particularly during reading, anticipation and postposition, the various types of misreading, unintelligible contraction of reports, with omission of essential factors, perplexity in public, explosion-like utterance of several syllables or of longer words, incapacity to syllabize and frequent consternation, with opening of the mouth and eyes and closure of the larynx. These patients often have an especial capacity for memorizing, but on the other hand, they have trouble in finding words; they have a tendency to breathe in the middle of a sentence; the melody of the speech is stereotyped; the speech is either unusually loud or low; frequently there is a paretic hoarseness; stammering mistakes are rather frequent. Especially noteworthy is the fact that there is usually a positive family history.

Moreover, all situations that result in fatigue and reduce the attention cause an exacerbation of this speech defect, whereas all situations that necessitate concentration and attention, improve this disorder, and in this respect it is the opposite of stuttering, which is intensified by attention and concentration. The author points out that there is a relationship between the described disorder and aphasia and that patients with aphasia have many symptoms that also occur in this disorder.

In discussing the therapy, Weiss points out that against the tachylalic factor slow speaking is directed. In order to concentrate the attention during reading and to eliminate the imagination, the author recommends reading by means of a perforated card or the reading of a foreign language or an incomprehensible text. He has found beating of the syllables with the fingers especially helpful.

EDITOR'S ABSTRACT.

Directory of Otolaryngologic Societies *

FOREIGN

Collegium Oto-Rhino-Laryngologicum Amicitiæ Sacrum

President: Prof. Gunnar Holmgren, Karolinska Mediko-Kirurgiska Institutet, Stockholm, Sweden.
Secretary: Prof. Dr. C. E. Benjamins, Verlengde Heereweg, 143 Groningen, The Netherlands.

NATIONAL

American Medical Association, Scientific Assembly, Section on Laryngology, Otology and Rhinology

Chairman: Dr. Robert F. Ridpath, 1737 Chestnut St., Philadelphia.
Secretary: Dr. Gordon B. New, Mayo Clinic, Rochester, Minn.
Place: Atlantic City, N. J. Time: June 7-11, 1937.

American Academy of Ophthalmology and Otolaryngology

President: Dr. Frank E. Burch, 408 Peter St., St. Paul.
Executive Secretary: Dr. William P. Wherry, 1500 Medical Arts Bldg., Omaha.
Place: Palmer House, Chicago. Time: Oct. 10-15, 1937.

American Bronchoscopic Society

President: Dr. Joseph C. Beck, 185 N. Wabash Ave., Chicago.
Secretary: Dr. Lyman Richards, 319 Longwood Ave., Boston.
Place: Atlantic City, N. J. Time: June 2, 1937.

American Laryngological Association

President: Dr. W. B. Chamberlain, 10515 Carnegie Ave., Cleveland.
Secretary: Dr. James A. Babbitt, 1912 Spruce St., Philadelphia.
Place: Atlantic City, N. J. Time: May 31 and June 1-2, 1937.

American Laryngological, Rhinological and Otological Society, Inc.

President: Dr. George M. Coates, 1721 Pine St., Philadelphia.
Secretary: Dr. C. Stewart Nash, 708 Medical Arts Bldg., Rochester, N. Y.
Place: Hotel Traymore, Atlantic City, N. J. Time: June 3, 4 and 5, 1937.

SECTIONS:

Eastern.—Chairman: Dr. D. C. Jarvis, Quarry Bank Bldg., Barre, Vt.
Southern.—Chairman: Dr. Charles D. Blassingame, P. & S. Bldg., Memphis, Tenn.
Middle.—Chairman: Dr. Alfred Lewy, 25 E. Washington St., Chicago.
Mid-Western: Dr. Frederick A. Figi, 436 Tenth Ave., Rochester, Minn.
Western.—Chairman: Dr. David R. Higbee, 3245 Fourth Ave., San Diego, Calif.

American Otological Society

President: Dr. Edmund Prince Fowler, 140 E. 54th St., New York.
Secretary: Dr. Thomas J. Harris, 104 E. 40th St., New York.
Place: Lido Club, Long Beach, N. Y.: Time: May 27-28, 1937.

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* Secretaries of societies are requested to furnish the information necessary to keep this list up to date.